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Use of RAPD markers to assess the genetic purity of castor hybrids

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Abstract

Assessment of genetic purity of four castor (*Ricinus communis* L.) hybrids was carried out using Random Amplification of Polymorphic DNA (RAPD) markers. Genomic DNA isolated from the individual plants of each parental line was bulked and screened for male parent specific marker and those were used against the individuals of each parental line to confirm their fidelity. The RAPD primers chosen were tried with the DNA of individual hybrid plants to assess the genetic purity.

Key words: Genetic purity of hybrids, grow out test, RAPD primers, castor

Introduction

Realization of the potential yields of hybrids in farmer's field depends primarily on the seed quality, especially of the genetic purity of the seeds. This is of special concern in case of a cross-pollinated crop like castor. Conventionally, the method used for the assessment of genetic purity is grow out test (GOT). GOT establishes purity through assessment of measurable morphological phenotypes of the hybrid plants to the profile of their parents. It is time consuming, laborious and is highly prone to environmental influence. A season may be lost to just establish the genetic purity of seeds by this method. Molecular markers, especially DNA markers offer a rapid and reliable way of establishing the purity of hybrid seeds. Since each of the parents of the hybrid is homogenous, genetically, and is different from each other, these characters being reflected in their DNA sequences, the hybrid must possess the DNA characters of both the parents. All DNA markers exploit this principle.

Random Amplification of Polymorphic DNA (RAPD) marker is a PCR based dominant DNA marker system and can be used even in the absence of sequence information of the crop concerned. Briefly, when tested on both the parents, a RAPD marker must give one or more amplicons specific to the male parent or both the parents. By choosing a RAPD marker that distinguishes the male from the female would amplify the male specific amplicon(s) in hybrid. In this article, successful adaptation of RAPD marker system to establish the genetic purity of four castor hybrids was demonstrated.

Materials and methods

Seeds of the two hybrids *viz.*, DCH-32 (LRES-17 x DCS-5) and DCH-519 (M-574 x DCS-78) along with their parents were grown in pots. Genetically pure seeds of GCH-2 (VP-1 x JI 35), GCH-5 (Geetha x SH-72) and their parents were obtained from PC Unit, Gujarat and grown. Genomic DNA was isolated from leaves of individual plants of hybrids and parents using standard methods (Sambrook *et al.*, 2001) and the DNA was visually quantified by running in 0.8% agarose gel and used for PCRs. Individual samples diluted to required concentration (5-10ng) were used for RAPD analysis of bulked DNA of the parents. Markers showing differences in the bulk analysis between parental lines were used to screen individual parental plants for the faithfulness of the marker. Operon primers were used for screening and primers which gave robust banding profiles were selected. PCR reaction was performed in 15 µl reaction volume containing 10mM Tris-HCl (pH-8.3), 50mM KCl, 5-10 ng of genomic DNA, 1U Taq DNA polymerase (3U/µl) (Bangalore Genei), 0.4 µM primer, 1X assay buffer with 1.5 mM $MgCl_2$, 2.5mM each of dNTPs and the volume made up with double distilled water. PCR cycling conditions used were, an initial denaturation at 94°C for 3 min, followed by 45 cycles of denaturation at 92°C for 30 sec, annealing at 36°C for 45 sec, extension at 72°C for 7 min, and finally were incubated at 4°C. The total PCR product along with loading dye was loaded on1.5% agarose gel and electrophoresed under standard conditions with a voltage of 3-5 v/cm. The gel was examined and photographed under UV transilluminator after the completion of electrophoresis. Primers that gave male specific bands were identified and the PCR analysis was repeated with individual plants of the parents to confirm the results. Once confirmed, the chosen primers were used with the individual plant DNA of the hybrids to assess the utility of these primers in purity assessment of the selected hybrids GCH-2, GCH-5, DCH-32 and DCH-519.

Results and discussion

Preliminary analysis of identifying RAPD primers that gave male specific bands was carried out with the bulk DNA of parents. In this analysis, many primers gave positive results. The primers that gave faint male specific bands were not considered for further analysis. Also, many of the primers were discarded when they were not consistent on repetition. The selected primers were tested with the individual plant DNA of parents to confirm that the results were consistent at individual plant level. Based on these criteria, among the 200 primers tried for the hybrids, 1 to 2 primers/hybrid were found promising that gave male specific bands on repeated PCRs. The primers were further validated at the individual plant level to assess their utility in estimating the genetic purity of the respective hybrids. With DCH-32 hybrid, primer OPE12 gave a male specific band of 1.2 kb (Fig. 1) and female specific band of 1 kb (Fig. 1) while the primer OPC9 gave a male specific band of 3.5kb (Fig. 2) with all the individuals and thus proved equally suitable for seed purity assessment. However, with DCH-519, only primer OPE12 gave a male specific band of 1.2 kb (Fig. 3) with consistent results at individual plant level. For GCH-2 (Fig. 4) and GCH-5 (Fig. 5), primers *viz.*, OPL12 and OPAE19, respectively, proved suitable RAPD markers for hybrid purity assessment

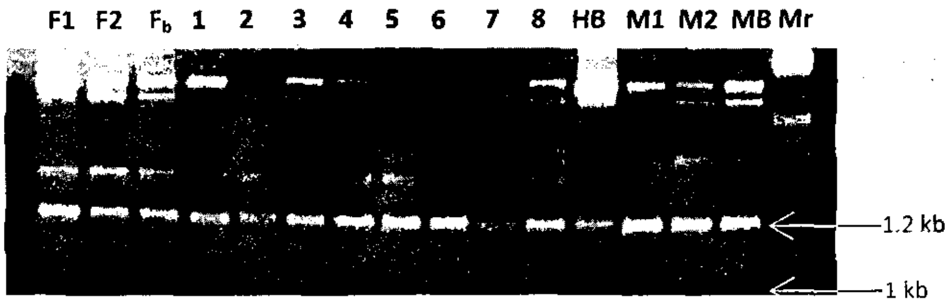

Fig. 1. RAPD analysis with individuals of DCH-32 using the primer OPE12

This primer produced a female specific amplicon of 1Kb and a male specific amplicon of1.2Kb.

F - Female, F_b - Female bulk 1 to 8 - Hybrids,
HB - Hybrid bulk M - Male, MB - Male bulk

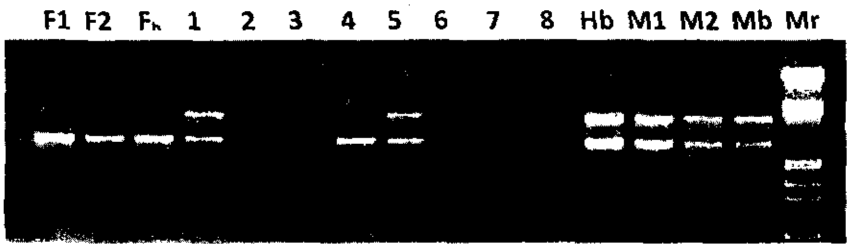

Fig. 2. RAPD analysis with individuals of DCH-32 using the primer OPC9

F - Female, F_b - Female bulk, 1 to 8 - Hybrid,
Hb - Hybrid bulk, M - Male, Mb - Male Bulk

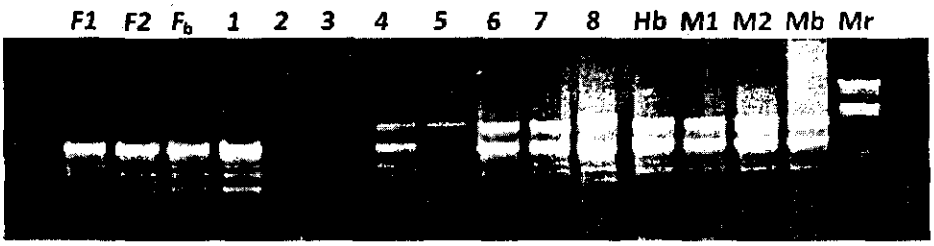

Fig. 3. RAPD of DCH5-19 individuals with the primer OPE12

F - Female, F_b - Female bulk, 1 to 8 - Hybrid,
Hb - Hybrid bulk M - Male, Mb - Male Bulk

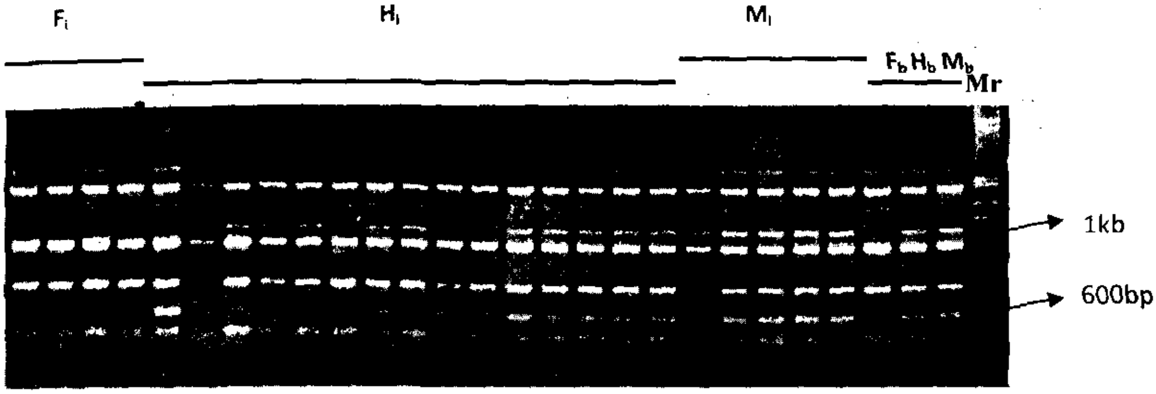

Fig. 4. RAPD of GCH-2 individuals with the primer OPL12 primer

F_i - Female, F_b - Female bulk, H_i - Hybrid,

H_b - Hybrid bulk, M_i - Male, M_b - Male bulk

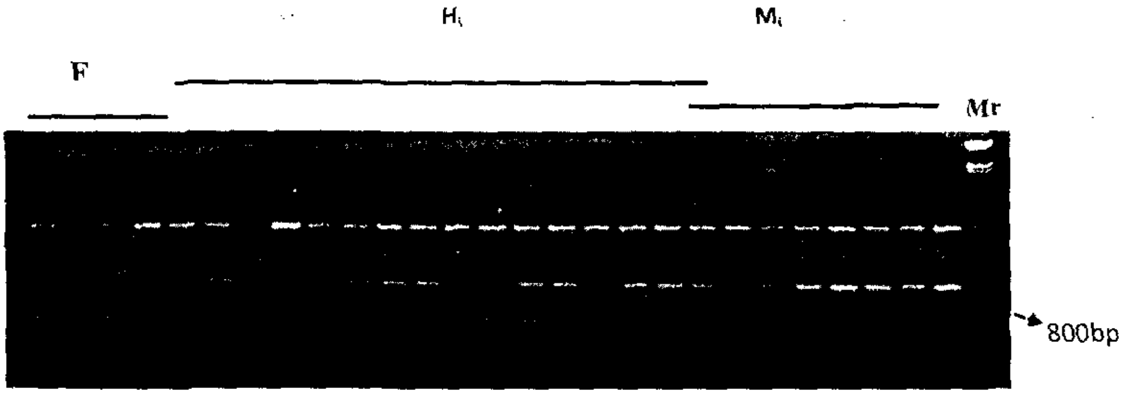

Fig. 5. RAPD of GCH-5 individuals with the primer OPL19 primer

F_i - Female, H_i - Hybrid, M_i - Male,

The basic principle in hybrid purity assessment is to look for dominant character(s) in the hybrid that are contributed by the male parent. *In other words, the selected dominant character(s) must be absent in the female so that their presence in the* hybrid indicate the contribution of the genome from male. RAPD being a dominant marker system, exactly the same analogy could be extended if one could identify RAPD markers that are present only in the male parent genome. In the present study, this principle was adopted and RAPD primers that give male specific bands were identified. *It was further* demonstrated that the identified markers could be used for assessing the hybrid purity in four hybrids. In literature, there were many reports of using RAPD markers for genetic purity assessment in several crops such as tomato, chilli, cauliflower, cabbage, watermelon, cotton and sorghum (Akhare *et al.*, 2008; Hashizume *et al.*, 1993 and Paran *et al.*, 1995). The results showed that RAPD profiles were quite repeatable under standard laboratory conditions.

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Development and validation of gene construct for inflorescence specific expression of *Ethylene Response Factor 1 (ERF1)* from *Arabidopsis* for conferring *Botrytis* tolerance in castor

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Abstract

Plants possess inducible defense systems to oppose attack by pathogens. The major defense related pathways known till date which work against the necrotrophic fungi involve ethylene (ET), and jasmonic acid (JA). Ethylene plays an important role in plant defense responses to necrotrophic pathogens. To investigate the contribution of this compound in defense response of castor to the inflorescence specific fungal pathogen *Botrytis ricini*, a defense regulatory gene ERF1 (*Ethylene Response Factor 1*) was studied in the model plant tobacco. Plants expressing *ERF1* under an inflorescence promoter AtACS5 were analysed both at the DNA and RNA level by PCR and RT-PCR, respectively. The expression was directed only in the inflorescence which is the target region of infection by the necrotrophic fungal species of *Botrytis*.

Keywords: Pathogens, necrotrophic fungi, ethylene, *ERF1*

Introduction

Plants have various defense responses to defend themselves against pathogens. Among the various defense responses ethylene defense regulatory genes are important signaling molecules produced by plants which regulate in positive or negative crosstalk with jasmonate subsets of genes involved in defense against necrotrophic microorganisms (Memelink, 2009). Ethylene signaling plays a major role for plant defense against necrotrophic fungi (Glazebrook, 2005). The transcription factor *ERF1* integrates signals from jasmonic acid and ethylene defense signaling pathways essential for the necrotrophic fungal resistance in plants (Farmer *et al.*, 2003; Guo and Ecker, 2004). *Botrytis*, a necrotrophic fungus, infects the inflorescence, the economic part of the plant in most cases. Localized expression of *ERF1* in the inflorescence would induce resistance in plants against this devastating fungi to a maximum limit as the over-expression of this gene enhances resistance in many cases.

Materials and methods

Isolation of the floral specific promoter AtACS5 and ERF1 gene from Arabidopsis: Standard PCR procedures were followed to isolate AtACS5 promoter (GenBank acc no: L29260) and the ERF1 (At3g23240) gene from Arabidopsis by using specific primers designed based on the sequences available in public domain (www.ncbi.nlm.nih.org). The primers were designed with appropriate restriction enzyme sites included at the 5' ends to facilitate their cloning in appropriate orientation. Initially, the amplicons of promoter and the gene were cloned in T/A cloning vector and were sequenced for confirmation. The confirmed sequences were cloned in pCAMBIA1300 in proper direction to realize the gene construct. The confirmed pCAMBIA:AtACS5-*ERF1*-PolyA plasmid was transferred into *Agrobacterium tumifacieans* strain LBA4404 by freeze-thaw method of transformation.

Tobacco transformation: Tobacco transgenics were developed by co-cultivating the tobacco leaf discs using the pCAMBIA 1300 AtACS5-*ERF*-PolyA vector transformed *Agrobacterium* strain LBA4404. The explants were co-cultivated on Murashige and Skoog medium containing 1mg/l BAP and 0.1mg/l NAA (BN-medium). The co-cultivated explants were transferred to BN medium supplemented with 50mg/l Hygromycin as the selection agent and maintained for two weeks at 20 to 22°C with cycles of 16h light and 8h darkness to obtain the putative transgenic shoots. The shoots on selection were transferred to elongation and rooting medium for producing the complete putative transgenic tobacco plantlets which were acclimatized in the green house.

Fig. 1. Development of transgenic tobacco expressing *ERF1* gene

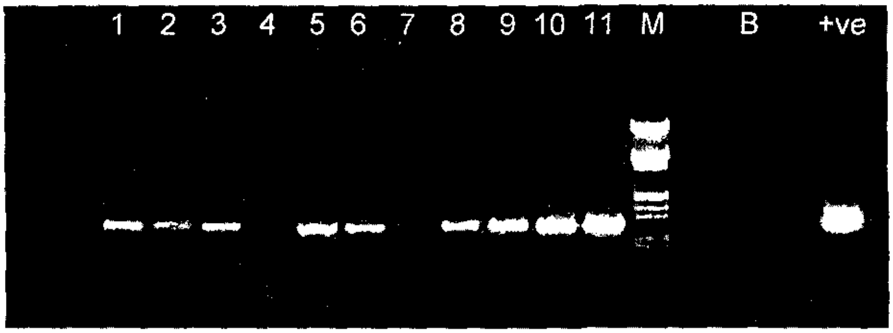

Fig. 2. PCR confirmation of ACS5-AMV-*ERF1*-PS tobacco transgenics

Lane 1-11: ACS5-AMV-*ERF1*-PS tobacco transgenics; Lane M: Lambda EcoRI/HindIII double digest Marker; Lane B : PCR blank; Lane +ve: PCR positive

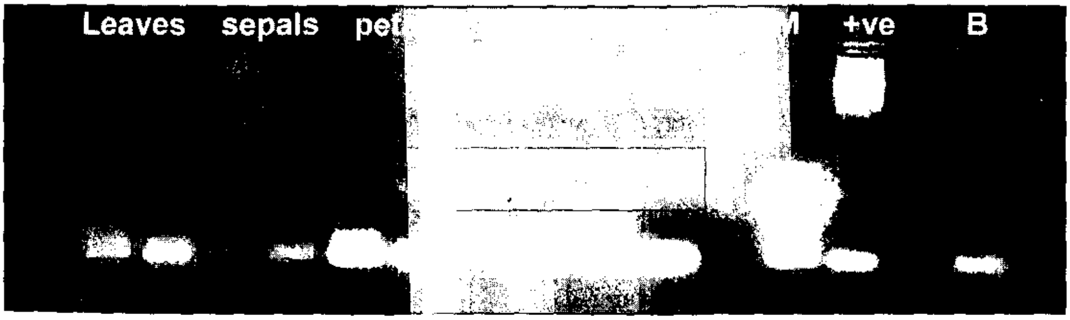

Fig. 3. RT-PCR confirmation of *ERF1* gene in tobacco transgenics

cDNA synthesized from RNA extracted from different parts (as indicated) was used for the RT-PCR with ERF1 specific primers.

M: Marker; +ve: Positive control (plasmid DNA); B: Blank control

Confirmation of transgenic shoots using PCR and RT-PCR: The genomic DNA from the putative ERF1 tobacco transgenics was isolated by CTAB method of genomic DNA extraction (Doyle and Doyle., 1990). The presence of the ERF1 gene cassette was analyzed by gene specific PCR using 10ng of the genomic DNA. The floral specific expression of the gene was assessed by isolating the RNA from the leaves (mature and young), different parts of the flower, *viz*., sepals, petals, stamens and stigma and checked for the expression by using the reverse primer of the gene for synthesizing the first strand of cDNA by RT-PCR. Further confirmation was done by PCR using the gene specific forward and reverse primers.

Results and discussion

The floral specific promoter AtACS5 (Wang *et al*., 2005; Tang *et al*., 2008) was isolated and confirmed. This confirmed fragment was cloned into the binary vector pCAMBIA1300. The *ERF1* gene was isolated from the genomic DNA of Arabidopsis (At3g23240) by PCR using primers specific for the gene. The isolated gene was cloned in InsT/A cloning vector and confirmed by PCR and restriction digestion. The clone was confirmed by sequencing with M13 forward and reverse primers. The confirmed clones, harboring the full length *ERF1* gene with no mutations were cloned downstream of AtACS5 and upstream of a PolyA terminator in pCAMBIA 1300. The developed construct was confirmed both by PCR and restriction digestion and was mobilized into *Agrobacterium* strain for transformation of tobacco. Tobacco transgenic plants were realized using the standard leaf-disc transformation method (Fig. 1). The putative transgenic plants were analysed for the presence of the transgene using gene specific PCR (Fig. 2). To ascertain the expression of the introduced gene, RT-PCR was performed. As the promoter used is from Arabidopsis and the expression pattern of the promoter in tobacco is not well understood, RT-PCR was performed with total RNA isolated from different plant parts. RT-PCR analyses indicated that the expression of the introduced gene was predominant in the floral parts and was absent in leaves and sepals.

Plants are subjected to attack by a wide variety of microbial pathogens. In response, they express numerous defense mechanisms, many of which are induced by pathogen attack. Appropriate regulation of defense responses is important for plant fitness, as activation of defense responses has deleterious effects on plant growth. It has been suggested that effective defense against biotrophic pathogens is largely due to programmed cell death in the host, and to associated activation of defense responses regulated by the salicylic acid-dependent pathway. In contrast, necrotrophic pathogens benefit from host cell death, so they are not limited by cell death and salicylic acid-dependent defenses, but rather by a different set of defense responses activated by jasmonic acid and ethylene signaling. The transcription factor *ERF1* integrates signals from JA and ET defense regulated pathways on necrotrophic pathogen attack (Glazebrook, 2005). In Arabidopsis, the AP2/ERF-domain transcription factor family comprises 122 members (Nakano *et al*., 2006). Overexpression of *ERF1* results in activation of many defense-related genes and suppresses the defects in defense-related gene expression caused by *ein2* and *coi1*. Plants overexpressing *ERF1* a closely related member of the AP2/ERF-domain family, were previously shown to have an elevated *PDF1.2* expression level and to be more resistant to *B. cinerea* (Lobo *et al*., 2002).

In addition, overexpression of the transcription factor *ERF1* which is encoded by a JA-inducible gene led to increased levels of *PDF1.2* expression (Pré *et al*., 2008). Hence, in the present study, inflorescence specific expression of ethylene transcription factor ERF1 was attempted using the floral specific promoter AtACS5. The reverse transcription results do conform to the expected expression in the floral parts and its absence in the leaves and further needs to be evaluated by castor transformations to develop a *Botrytis* resistant castor transgenic.

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Transgenic tobacco - as a model for identifying the most efficient PTGS technology at silencing ricin and RCA in castor, *Ricinus communis* L.

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Abstract

The present investigation was carried out with the objective of establishing a model system in tobacco for assessing the efficiency of different PTGS constructs developed for reducing ricin and *Ricinus communis* agglutinin (RCA) in castor. Tobacco plants were transformed, through *Agrobacterium*-mediated leaf-disc transformation, with a gene construct containing full-length ricin gene and independently with the five post transcriptional gene silencing (PTGS) constructs under CaMV 35S promoter. These plants were developed with the objective of crossing them with the plants expressing ricin gene so that in the progeny the efficiency of each of the PTGS constructs in silencing the ricin gene could be established. Transgenic tobaccos thus obtained, were confirmed by PCR.

Keywords: Ricin, RCA, PTGS, castor and tobacco

Introduction

Castor oilmeal, though endowed with around 25% balanced protein, cannot be used as animal feed as it contains highly toxic proteins such as ricin and RCA. If castor lines not producing ricin and RCA in the seed are realized, the oilmeal from such lines could be used as animal feed and it would be of national economic importance (Gandhi *et al.*, 1994). Since ricin and RCA genes share high levels of homology at the nucleotide level, it is surmised that these proteins could be eliminated or reduced to acceptable levels using powerful PTGS techniques by choosing appropriate gene segments conserved among their genes, so that transcripts of both are targeted for degradation

Suitable PTGS vectors have already been developed at the Directorate of Oilseeds Research (DOR), Hyderabad, by adopting three different viz., antisense RNA, intron hairpin RNA (ihpRNA) and silencing by heterologous 3' untranslated region (SHUTR) PTGS technologies to reduce/eliminate the levels of ricin and RCA proteins in the developing castor seeds. Three approaches have been envisaged, since it was reported that different strategies of silencing differ in their efficiency in silencing the target gene transcript and the best one will have to be identified empirically. The logistic requirement in such an exercise is the production of reasonably good number of independent transgenics with each of the vectors and then evaluate the transgenic plants for assessing the relative efficiencies of the silencing vectors. However, accomplishing this would be a daunting task in castor as the transformation protocols reported so far in this crop are of low frequency. This has necessitated a search for alternate model systems like tobacco to assess the efficiency and potential of the developed PTGS technologies in silencing ricin and RCA. Tobacco is a model plant with endospermic seed. It is known for its good regeneration and highly reproducible genetic transformation capability. Ricin gene has already been expressed in tobacco and it has been demonstrated that the ricin protein biosynthesis takes place exactly similar to what is seen in castor with the resultant protein having proper folding (Frigerio and Roberts, 1998). Thus, tobacco system harbouring different PTGS constructs could be crossed individually with transgenic tobacco plants expressing ricin and thus facilitate assessing the potential of the developed PTGS constructs by analyzing the ability of these constructs in reducing ricin gene expression in transgenic tobacco.

Materials and methods

All chemicals, media, antibiotics, growth hormones and ready-to-use kits work were of molecular biology grade and supplied by standard companies. Tobacco T-3 genotype obtained from the National Research Centre on Plant Biotechnology, New Delhi and *Nicotiana tabacum* cv. *xanti* obtained from International Crops Research Institute for the Semi-Arid Tropics, Hyderabad and maintained at DOR were used as plant material.

The basal vectors used for transformation of tobacco-pCAMBIA1300 and pCAMBIA2300, were obtained from CAMBIA (Center for Application of Molecular Biology to International Agriculture). The vectors, pCAMBIA2300 Ricin1.7kb and pCAMBIA1300 ihp-RA, ihp-RB, SHUTR-RA, SHUTR-RB, FLA/S-Ricin, developed earlier at DOR were used in this study. Standard *Agrobacterium tumefaciens* strain LBA4404 into which binary vectors were mobilized was used for plant transformation.

Standard *Agrobacterium*-mediated leaf-disc transformation protocol was followed to realize transgenics in tobacco. Leaf discs were cut aseptically and co-cultivated in MS media supplemented with BA (1.0 mg/l) and NAA (0.1 mg/l) for two days. This is followed by two subcultures each of fifteen days duration on to MS media supplemented with BA (1.0 mg/l) and NAA (0.1 mg/l) and cefotaxime and the respective selectable antibiotic marker - (shoot induction phase). The explants giving out shoots were then subcultured on to MS media supplemented with BA (0.5 mg/l) and cefotaxime and the respective selectable antibiotic markers (shoot proliferation and elongation phase). The elongated shoots were then rooted on half strength MS media with respective antibiotic selectable markers (rooting phase). DNA isolated from putative transgenic as well as control tobacco plants by modified Cetyl trimethylammonium bromide (CTAB) procedure of Doyle and Doyle (1987) was subjected to PCRs. Putative transgenics obtained were confirmed by PCR amplification of specific component sequences present in the construct. The PCR reaction mixture consisted of 20 ng of DNA, 0.2 μM each of the forward and reverse primers specific for the gene fragment, 1x final concentration of *Taq* DNA polymerase buffer [10 mM Tris-HCl (pH 9), 1.5 mM $MgCl_2$, 50 mM KCl, 0.01% gelatin], 100 μM of each dNTP, 1 unit of *Taq* DNA polymerase, and sterile water to make up the volume. The annealing temperature and extension time were determined based on the primers used and the expected product size.

Total RNA was isolated from putative transgenic as well as control tobacco plants as per the instructions given by the supplier of TRIzol® (Life Technologies). Putative transgenic plants that were positive in PCR analyses were subjected to transcript analysis by RT-PCR. The first-strand cDNA synthesis reaction was carried out following the instructions given by the supplier (Invitrogen).

Results and discussion

Genomic DNA isolated from the transgenic plants harbouring ricin gene and each of the five PTGS constructs independently was subjected to PCR analysis for presence of the introduced gene construct in the transgenic plants by using different primer combination for ricin A chain, ricin B chain, CaMV 35S promoter, catalase intron and polyA. In all the confirmations of the transgenic tobacco using PCR analyses, both the positive and negative controls gave the expected results indicating that the PCR conditions were ideal.

PCR analysis of transgenic plants expressing ricin full length gene:

Twenty six out of 31 putative transgenics harbouring full-length ricin gene analyzed showed the required product of 1.7kb with ricin primers indicating the presence of introduced gene in the shoots. However, the expected amplicon was very bright in 18 putative transgenics and faint in 8 putative transgenics (Fig. 1). The transgenics which were positive for the presence of intact full-length ricin gene cassette, were selected for RT-PCR analyses as these plants were expected to contain the ricin transcripts. RT-PCR analyses show that all the seven transgenics showed required product of 1484bp with ricin A chain forward and ricin B chain reverse primers indicating the expression of ricin [Fig. 2b(iii)]. But when the amplification was performed with ricin forward and ricin A chain reverse primers, expected fragment of 478bp was obtained in six transgenic plants [Fig. 2b(i)]. Absence of amplicon in one transgenic plant could be due to rearrangements in the introduced transgene or due to PCR failure. Amplification performed with ricin B chain forward and ricin reverse primers gave expected fragment of 431bp in all the seven samples [Fig. 2b(ii)]. Positive control DNA of pCAMBIA2300-FL-Ricin also gave the expected fragment in all the amplifications. cDNA from untransformed tobacco plant and blank (premix without cDNA) as negative controls did not give any amplification indicating the experimental set up was appropriate. Thus, from RT-PCR analyses, it could be established that the transgenic tobacco plants were expressing the introduced ricin gene.

PCR analysis of transgenic plants carrying silencing constructs:

PCR analysis of putative transgenic plants obtained with ihp-RA was carried out with 35S promoter forward primer and ricin A chain forward primer. The expected band of 770bp was obtained, in all the 27 putative transgenics (Fig. 3b). However, the expected band was faint in nine transgenics. Simlarly, the PCR analysis with putative transgenic plants obtained carrying ihp-RB cassette indicated that 19/30 plants were positive for the introduced vector (Fig. 4b). PCR analysis indicated that 7/11 and 6/11 plants were positive for the introduced gene cassettes with respect to putative transgenics carrying SHUTR-RA and SHUTR-RB cassettes respectively (Fig. 5b, 6b). All the 11 putative plants carrying FL-A/S-ricin were positive when tested for the transgene cassette (Fig. 7b).

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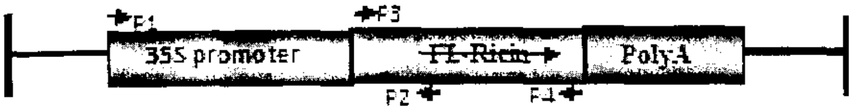

Fig. 1a. Schematic diagram of LBA4404::pCAMBIA 2300 Ricin 1.7kb construct showing the components and position of different primer binding sites

P1: 35S For; P2: ricin A chain Rev; P3: ricin For; P4: ricin Rev

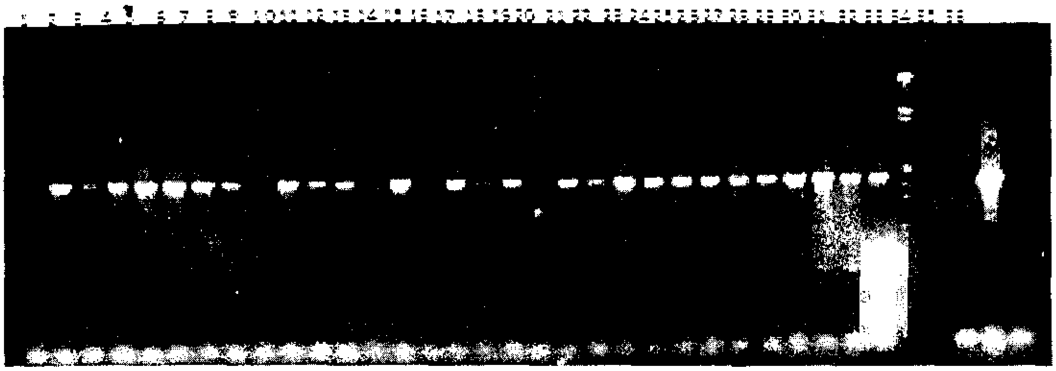

Fig. 1b. Confirmation of tobacco harbouring full length ricin gene by PCR with ricin forward and ricin reverse primers (expected amplicon size = 1.7kb)

Lane 1-31: Tobacco harbouring full length ricin gene; lane 32: E+H digesed λ DNA; Lane 34: untransformed tobacco; Lane 35: positive control (LBA4404::pCAMBIA 2300 R1.7kb); Lane 36: Blank (without DNA)

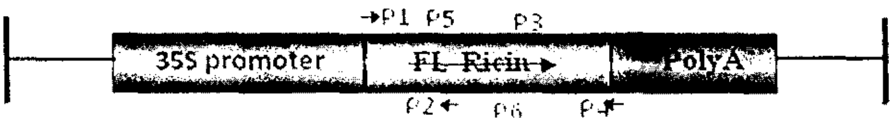

Fig. 2a. Schematic diagram of LBA4404::pCAMBIA 2300 Ricin 1.7kb construct showing the components and binding position of different primers

P1: *ricin For; P2: ricin A chain Rev; P3: ricin B chain For; P4: ricin Rev; P5: ricin A chain For; P6:* ricin B chain Rev

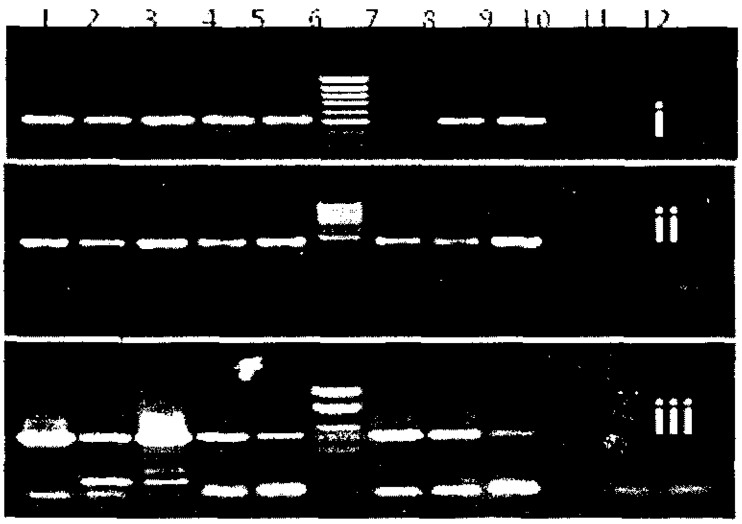

Fig. 2b. Confirmation of tobacco expressing ricin by RT-PCR

(i): With ricin forward and A chain reverse (expected amplicon size – 478 bp); (ii): With B chain forward and ricin reverse (expected amplicon size ~ 431 bp); (iii) with ricin A chain forward and ricin B chain reverse (expected amplicon size – 1484 bp)

Fig. 3a. Schematic diagram of ihp-RA construct showing the components and binding position of different primers

P1: 35S For; P2: Ricin A chain For; P3: Intron For; P4: ricin A chain Rev

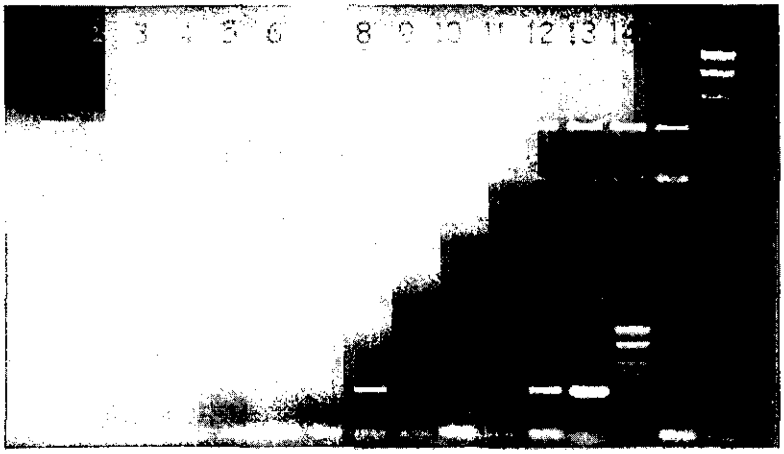

Fig. 3b. Confirmation of tobacco harbouring ihp RA silencing construct by PCR with 35S Forward and ricin A chain Forward (expected amplicon size = 770bp)

Upper panel: Lane 1-15: transgenic tobacco harbouring ihp RA silencing construct; Lane 16: E+H digested λ DNA

Lower panel: Lane 1-12: transgenic tobacco harbouring ihp RA silencing construct; Lane 13: positive control (KBA4404::pCAMBIA 1300 ihp-RA); Lane 14: E+H digested λ DNA; Lane 15: *untransformed tobacco; Lane 16: Blank (without DNA)*

Fig. 4a. Schematic diagram of ihp-RB construct showing the components and binding position of different primers

P1: 35S For; P2 Intron Rev

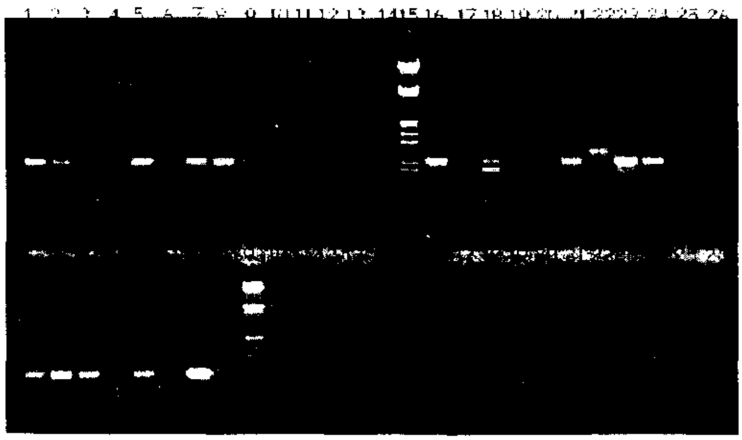

Fig. 4b. Confirmation of tobacco harbouring ihp-RB silencing construct by PCR with 35S Forward and intron Reverse (expected amplicon size = 931bp)

Upper panel: Lane 1-14 & 16-25: transgenic tobacco harbouring ihp-RB silencing construct; Lane 15: E+H digested λ DNA

Lower panel: Lane 1-5: transgenic tobacco harbouring ihp-RB silencing construct; Lane 7: positive control (LBA 4404::pCAMBIA1300ihp-RB); Lane 9: E+H digested λ DNA; Lane 10: Untransformed tobacco; Lane11: Blank (without DNA)

Fig. 5a. Schematic diagram of SHUTR-RA construct showing the components and binding position of different primers

P1: 35S For; P2: Intron Rev; P3: Intron For; P4: polyA Rev

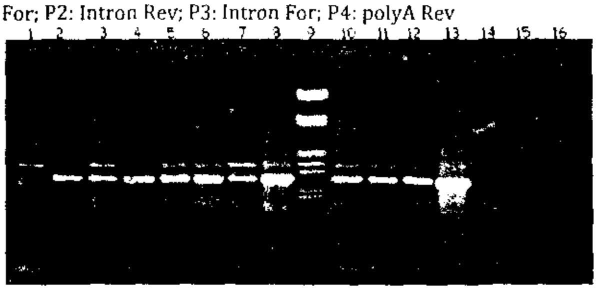

Fig. 5b. Confirmation of tobacco harbouring SHUTR-RA silencing construct with 35S Forward and intron Reverse (expected amplicon size-1200bp).

Lane 1-8 and 10-12: transgenic tobacco harbouring SHUTR-RA silencing construct; Lane 9: E+H digested λ DNA; Lane 13: posititve control (LBA4404::pCAMBIA1300SHUTR-RA); Lane 15: untransformed tobacco; Lane 16: Blank (without DNA).

Fig. 6a. Schematic diagram of SHUTR-RB silencing construct showing the components and the binding position of different primers.

Fig. 6b. Confirmation of tobacco harbouring SHUTR-RB silencing construct by PCR with 35S Forward and intron Reverse (expected amplicon size-1151bp)

Lane 1-8 and 10-12: transgenic tobacco harbouring SHUTR-RB silencing construct; Lane 9: E+H digested λ DNA; Lane 13: posititve control (LBA4404::pCAMBIA1300SHUTR-RB); Lane 15: untransformed tobacco; Lane 16: Blank (without DNA).

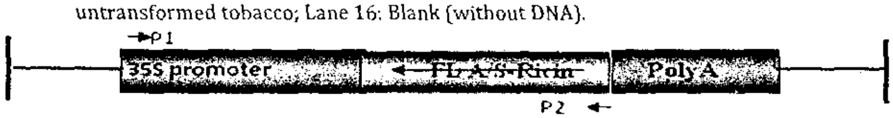

Fig. 7a. Schematic diagram of FL-A/S-Ricin construct showing the components and binding position of different primers.

P1: 35S For; P2: Ricin anti-sense For

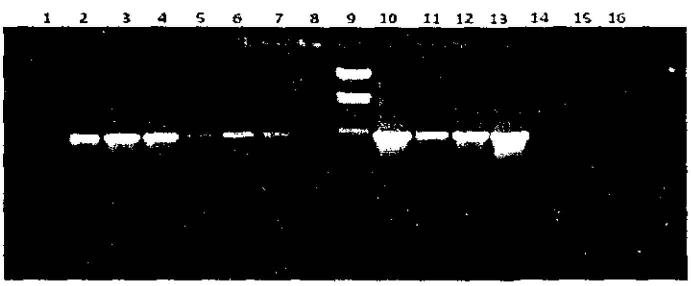

Fig. 7b. Confirmation of tobacco harbouring FL-A/S-Ricin silencing construct by PCR with 35S Forward and ricin anti-sense Forward (expected amplicon size- 1714bp)

Lane 1-8 and 10-12: transgenic tobacco harbouring FL-A/S-Ricin silencing construct; Lane 9: E+H digested λ DNA; Lane 13: posititve control (LBA4404::pCAMBIA1300FL-A/S-Ricin); Lane 15: untransformed tobacco; Lane 16: Blank (without DNA).

Towards functional analysis of ricin promoters

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Abstract

Ricin and *Ricinus communis* agglutinin (RCA) are the most toxic proteins present in castor oil meal, making it unfit for consumption as an animal feed. Ricin and RCA express and accumulate in endosperm. The present investigation aims at functional analysis of the already isolated ricin (supposedly endosperm-specific) promoters from castor (Ricinus communis L.) which were earlier isolated using inverse-PCR, as a prelude to silencing ricin and RCA in castor.

Keywords: Ricin, RCA, post transcriptional gene silencing (PTGS), endosperm-specific promoter, *in silico* studies, transient studies, bombardment

Introduction

The endosperm of castor (*Ricinus communis* L.) contains ricin and RCA, which accumulate to high levels and are not found in other tissues of the plant. The genes for these are shown to be very tightly regulated at the transcriptional level with their expression clearly restricted to the developing endosperm. If silencing molecules are to be expressed in endosperm tissues, the gene construct for the same must be driven by endosperm-specific promoter. This warranted isolation (Ashfaq *et al.*, 2009) and characterization of ricin-specific (endosperm-specific) promoters (reported herein), viz., ricin full-length promoter (FP) and ricin truncated promoter (TP). To effect functional analysis of the ricin promoters, transient studies were carried out with the four constructs developed (results unpublished). The transient studies included particle bombardment and *Agrobacterium*-mediated transformation of developing seeds of castor (47 days after pollination).

Materials and methods

The chemicals and ready to use kits used in all the experiments were of molecular biology grade.

Seeds of DCS-9 were used for all transient studies. Four constructs have been used in the present study. These included (1) LBA4404:: pCAMBIA 1391Z TP, (2) LBA4404:: pCAMBIA 1391Z FP, (3) LBA4404:: pCAMBIA 1391Z CaMV35S, (4) LBA4404:: pCAMBIA 1391Z.

To effect bombardment of castor seeds, the plasmid DNAs of the four constructs in the *E.coli* strain DH5α have been used. To effect *Agrobacterium*-mediated transformation of developing seeds of castor, the four constructs in the background of LBA4404 strain have been used.

Readymade mix of Murashige and Skoog (1962) medium supplemented with 3% sucrose constituted the pre-osmoticum and post-osmoticum media. Decoated seeds were surface sterilized with 0.1% (w/v) of mercuric chloride for 8.0 min and rinsed thoroughly four times in sterile distilled water. Whole endospermic seeds collected at 47 days after pollination (DAP) were aseptically pre-incubated on pre-osmoticum medium and stored in the dark.

Transformation with particle gun: Following pre-incubation, whole seeds of castor were selected for bombardment with the biolistic PDS-1000 He system (BioRad Hercules, CA). About 9 endosperms were arranged on Whatman No.1 filter paper in a circle of 1.5 cm diameter in the centre of a 9.0 cm petriplate with osmoticum (0.2 M each of sorbitol and mannitol) and plasmolysed for 2 h prior to bombardment. The constructs pCAMBIA1391Z FP, pCAMBIA1391Z TP, pCAMBIA1391Z CaMV35S *gus* and the basal vector, pCAMBIA1391Z were used for the experiments.

Preparation of microcarriers: Microcarriers were coated with 6 μg of plasmid DNA/50 μl particle preparation (3 mg microcarrier/50 μl) using the $CaCl_2$ (50 μl, 2.5 M) and spermidine (20 μl, 0.1 M) precipitation method according to the manufacturer's instructions to give a DNA concentration of 2 μg/mg of microcarriers. Following precipitation, the supernatant was removed and pellet was washed with 300 μl of absolute ethanol. After washing, the particle DNA pellet was resuspended in 50 μl of absolute ethanol for 6 bombardments. Care was taken to ensure uniform particle distribution and minimize agglomeration. Bombardments were done under a vacuum of 27 inches of Hg, a 25 mm distance from rupture disc to macrocarrier and a 10 mm macrocarrier flight distance for all the bombardments. The parameters tested included rupture disc pressures (1,100 psi), microprojectile travel distance (6 cm) and microcarrier (gold particle size 1.0). Non-bombarded seeds and seeds bombarded with uncoated microcarriers were used as controls. Following bombardment, the explants were kept in dark at 25°C for 2 h and then transferred to MS-medium containing 3% sucrose and after 2 days, the explants were checked for β-glucuronidase GUS activity. Transient GUS assays were performed 48 h after bombardment by incubating the tissues in assay buffer (0.05 M NaH_2PO_4 with 500 mg/l X-Gluc and 30% Triton X-100) for 12 h at 37°C, after which they were destained and stored in 70% alcohol (Jefferson *et al.*, 1987).

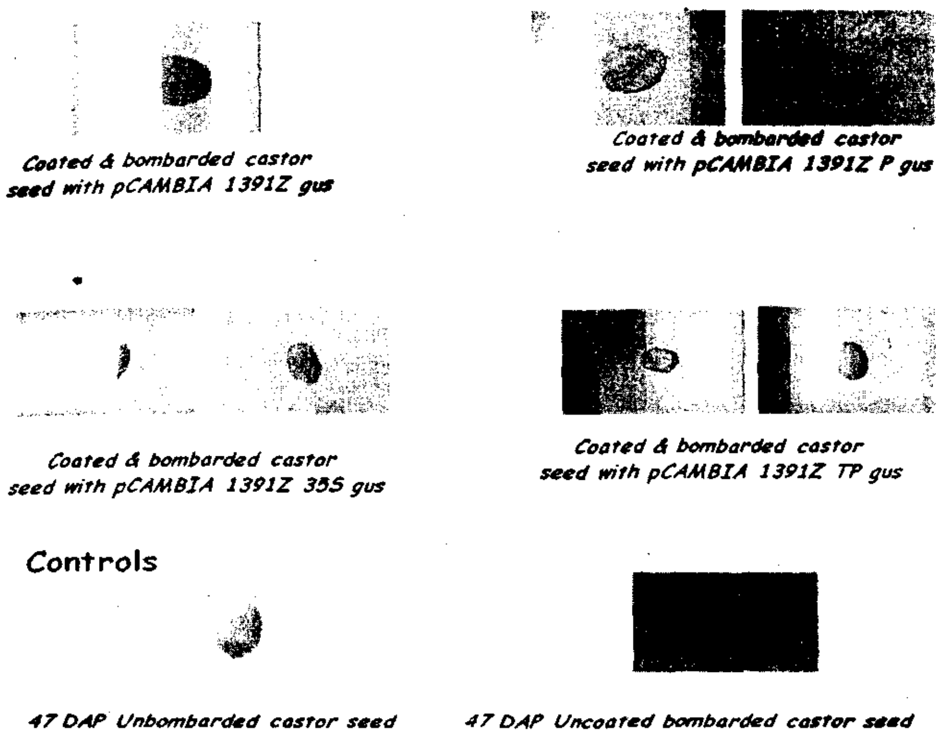

Fig. 1. Particle gun-mediated bombardment of developing seeds of castor

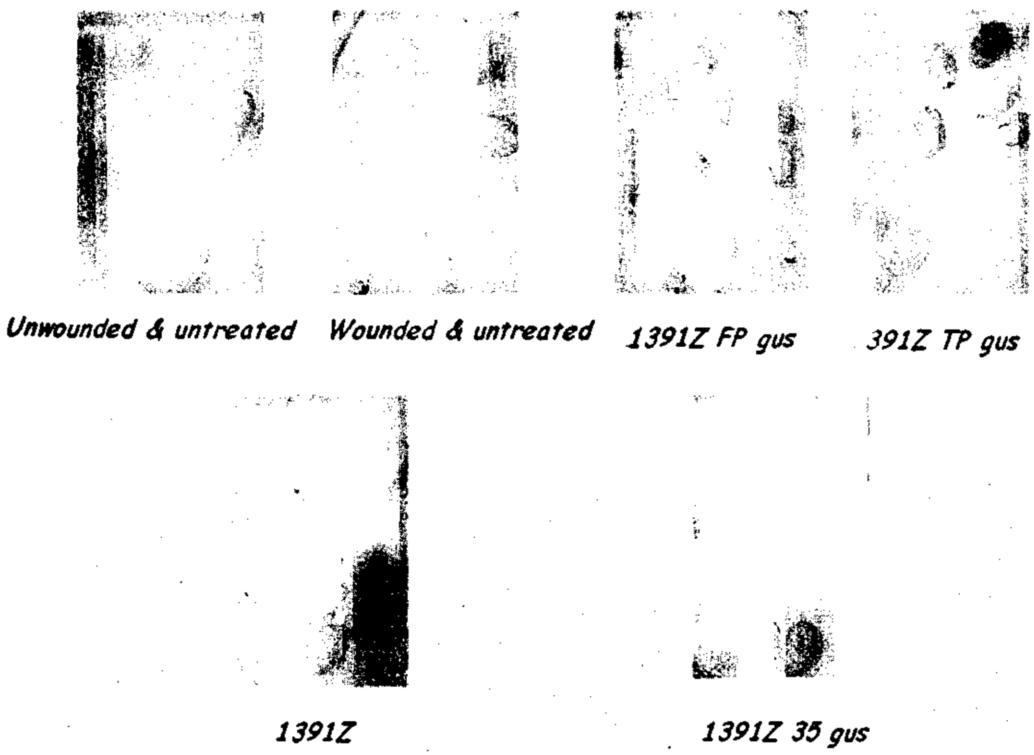

Fig. 2. Agrobacterium-mediated transformation of developing seeds of castor castor

Results and discussion

Transient assays with the developing seeds of castor

Since the main aim of the present investigation was to effect PTGS of ricin and RCA in the endospermic tissue of castor, transient assays were performed with the above four constructs possessing *gus* to validate the tissue-specificity of the ricin promoters in castor. The assays included microprojectile bombardment of developing seeds of castor (47 DAP) and *Agrobacterium*-mediated transformation of developing seeds of castor (47 DAP). The transient assays were performed with developing seeds of castor i.e., 47 DAP since the transcripts of ricin and RCA are known to peak at 47 DAP (Chen *et al.*, 2005).

Particle gun-mediated bombardment of castor seeds

Seeds of the castor cultivar DCS-9 (Jyothi) were used in all the experiments. The developing seeds of castor were bombarded using gene gun model "Biolistic PDS-1000/He Particle Delivery System". The plasmid DNA concentration of each of the above four constructs used for bombardment was 2 μg/ l. The parameters tested included Helium pressure of 1100psi, target distance of 6 cm and a total of 3 replications for each of the four constructs. A total of 9 seeds were bombarded per replication. Two controls were also included in the study, *viz.*, the uncoated (without DNA) bombarded seeds and unbombarded seeds.

The seeds bombarded with 1391Z FP yielded blue colouration all along the endosperm, but prominent, thick, concentrated blue foci could not be visualized. With 1391Z TP construct, the intensity of blue colour of endosperm was little less when compared with the one bombarded with 1391Z FP.

Construct 1391Z 35S *gus* yielded blue colour which was diffused all along the endosperm. Same was true in the basal promoter-less binary vector, 1391Z, though the intensity being less compared to 1391Z 35S *gus*. The control, uncoated but bombarded yielded very faint blue colouration. The unbombarded control did not show any colouration. Though three replications were performed for each of the constructs, there was a lot of inconsistency in the patterns of blue colouration as a result of bombardment. An attempt has been made to assess relative expression levels, qualitatively, by observing the density of *GUS* staining rather than rigorously quantitating the numbers of stained spots (Plate 1).

Agrobacterium-mediated transformation of castor seeds

Decoated, sterilized seeds of castor (47 DAP) of variety DCS-9 were subjected to wounding followed by co-cultivation with each of the four constructs. After co-cultivation, they were assayed for *GUS* activity. The controls included unwounded and untreated (without co-cultivation) seeds and wounded and untreated seeds.

The seeds wounded and co-cultivated with 1391Z FP yielded thick blue colouration all along the endosperm. With 1391Z TP construct, the intensity of blue colour of endosperm was similar to the one bombarded with 1391Z FP. Construct 1391Z 35S *gus* yielded blue colour which was diffused all along the endosperm.

Same holds true in the basal promoter-less binary vector, 1391Z, though the intensity being less compared to 1391Z 35S *gus*. The control, wounded and untreated, yielded very faint blue colouration. The unwounded and untreated control resisted any change and was true to its type (Plate 2). Though this approach is incipient and unsophisticated to address the tissue-specificity of constructs carrying a variety of regulatory regions, it is a quick and easy method to assess promoter activity. Preliminary analysis using this approach suggests the expression of ricin promoters in developing seeds of castor.

Acknowledgement

The financial assistance provided by Department of Science and Technology, Government of India in the form of research grant to carry out the work is duly acknowledged.

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Modification of *ThEn42* gene for improved tolerance against *Botrytis* in castor

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Abstract

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop that is produced largely in India. Grey mold disease caused by *Botrytis ricini* (Godfrey), a necrotrophic fungus, has become a serious threat to castor cultivation, especially in Peninsular India. To circumvent the problem, development of transgenic castor expressing antifungal genes was envisaged. Chitinases are amongst the widely used antifungal genes for generating fungal resistant plants. *ThEn 42* gene encoding a 42Kd endochitinase from *Trichoderma harzianum* has shown to impart tolerance to *Botrytis* both *in vitro* and *in vivo*. In the present study, the native *ThEn 42* gene was modified by optimization of the codon composition, GC content and inclusion of the regulatory sequences for achieving high level gene expression in castor. Codon optimization was carried out using the algorithm synthetic gene designer by using one amino acid-one codon approach to achieve an optimality factor 0 and codon adaptation index 1. To boost the translation efficiency by means of G residue at +4 position a GCT codon, and an A-tract of ten adenine residues was incorporated. AMV 5'UTR was employed to increase the mRNA stability. A 21 amino acid signal peptide from plant source was used for secreting the protein into the apoplastic space. Oligonucleotide primers were designed for the modified *ThEn 42* sequence of 1397 nucleotides which were subsequently used for PCR based synthesis. The overlap extension PCR product was cloned into T/A vector and the sequence was confirmed. This is the first report of fully optimized and modified *Trichoderma endochitinase* gene for high level gene expression in castor.

Keywords: *ThEn42*, codon optimisation, *Botrytis*, heterologus expression

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop of arid and semi-arid regions of the world. Castor is grown in 1.26 million ha of area with 1.14 m. tonnes of production and 902 kg/ha of productivity in the world where India shares 59.1% of the area and 64% of the total production with 1146 kg/ha of productivity. Thus, India is the world leader in castor seed production meeting about 90% of the world's castor oil requirement and earns about 1000 crores of foreign exchange by exporting 3.0 lakh t of castor oil. Although production has increased by five fold in the last 50 years through conventional plant breeding approaches and other agro-techniques, national production has fallen below the expected production in recent years. Every year there is an average seed yield loss of 15% in castor due to different diseases.

Of late, grey mold disease caused by *Botrytis ricini* (Godfrey) has become a serious threat to castor cultivation, especially in peninsular India, where the crop is devastated during cyclonic and incessant rains. The genus *Botrytis* is amongst the earliest studied plant pathogens belonging to the family *Sclerotiniaceae*. It is a broad host range necrotrophic fungus invading over 200 plant species. The fungal cell wall, together with the plant cell wall, forms the interface where the initial plant-microbe interaction occurs and is the site of events that determine the outcome of the interaction. The host cell wall is the primary target during *Botrytis* growth on plant tissue. It is evident that, for successful infection by the fungus, penetration of the plant cell wall is essential. Plants overexpressing cell wall degrading enzymes like chitinases are shown to be highly tolerant to fungal pathogens. Transgenic tobacco (*Nicotiana tabacum*) and potato (*Solanum tuberosum*) plants overexpressing an endo-chitinase (*ThEn42*) from *Trichoderma harzianum* have been shown to be highly tolerant to the foliar pathogens *Alternaria alternata, Alternaria solani* and *Botrytis cinerea*, and also to the soil-borne pathogen *Rhizoctonia solani* (Lorito *et al.*, 1998). Interestingly, *ThEn 42* expression in tobacco had shown abiotic stress tolerance in addition to biotic stress tolerance. Heterologous expression of the chitinase in rice has shown to reduce the sheath blight disease index by about 62% (Shah *et al.*, 2004). A recent report of co-expression of *ThEn 42* in Banana with Stillbene synthase gene from grape and a SOD gene from Tomato has shown improved tolerance to *Botrytis* (Vishnevetsky *et al.*, 2010). The present investigation was conducted to carry out codon optimization and modify *ThEn 42* gene for high level gene expression in castor

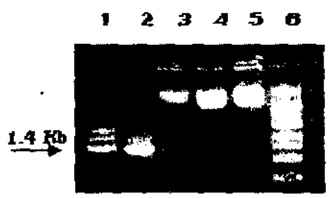
Materials and methods

The 1275 bp cDNA sequence of *Trichoderma* endochitinase gene (accession no.X79381) was analyzed for codon usage pattern similarities with most preferred codon usages of highly expressed genes of dicot plants. The codon frequency data for *Arabidopsis* and *Ricinus communis* obtained from CUTG website http://www.kazusa.or.jp/codon/ (Codon Usages Tabulated from Gene Bank) were taken as references. A 36 nucleotide 5' untranslated leader of the coat protein mRNA of alfalfa mosaic virus (AMV) was incorporated to increase mRNA stability and enhance translation efficiency (Gehrke *et al.*, 1987). Dicot plant preferred translation initiation context with ATG GCT (Kozak *et al.*, 1997) was attained by incorporation of a GCT codon at second position in the modifed chitinase gene. Ribosomal binding efficiency was augmented by inclusion of A-tract of ten Adenine residues downstream of the AMV 5'UTR. A 63 nucleotide plant apoplastic target signal was deployed for delivering the protein into the apoplastic space. Codon optimization of the modified 1400 chitinase and designing of the oligonucleotide primers was done with The Synthetic Gene Designer software program (http://www.evolvingcode.net/codon/sgd/index.php) (Wu *et al.*, 2006). Oligonucleotide size was chosen to be 60 nucleotides with overlap region of 15 nucleotides between the primers. Thirty primers were designed along with two short external primers carrying restriction enzyme sites of SalI and EcoRI for facilitating cloning. Bioserve biotechnologies synthesized and supplied all the primers. An overlap extension PCR was performed as follows: a master mix of all the 30 primers was made with final concentration of each primer being 2pM/μL. 0.5 μL of the reaction mixture was taken to which 1.5 μl of two short external primers were added at a concentration of 20 pM/μl. PCR was performed with KOD DNA polymerase from *Thermococcus kodkaraensis* supplied by Novagen. PCR was conducted for 30 cycles with denaturation at 90°C for 30 seconds, annealing at 60°C for 30 seconds, extension at 72°C for 20 seconds and a final extension at 72°C for 5 min. The PCR product was cloned into TA vector (Fermentas).

Results and discussion

The cDNA sequence of *Trichoderma* endochitinase gene encodes a 424 amino acid protein which exhibited 75% (957/1275 identities) similarity at the nucleotide level to the fully optimized gene and 318 nucleotides were altered in the optimized gene. The native coding sequence had only one third similarity with the most frequently used codon usage of the dicots. Thirty six per cent of the total native codons in chitinase were the least preferred codons in Dicots especially in *Arabidopsis* and Castor. Thirty per cent of the native codons were moderately preferred. Codon adaptation index (CAI) of 0.670 was observed for the native gene with a GC content of 53.33%.One amino-one codon approach was adopted for codon optimization with the Synthetic Gene Designer to generate Fully optimized chitinase gene with an optimality factor 's = 0' and Codon adaptation index '1' which altered the GC content to 36%. Expression of the *cryIA(b)* gene when compared to partially modified (3% nucleotide difference) had a 10-fold higher level of insect control protein in tobacco and tomato. Fully modified (21% nucleotide difference) *cryIA(b)* and *cryIA(c)* had a 100-fold higher level of CRYIA(b) compared with the wild-type gene (Perlak *et al.*, 1991). Kang et al., (2004) reported the expression levels of codon modified Cholera toxin B subunit (CTB) production to be approximately 15-fold higher compared to tobacco plants that were transformed with the native bacterial CTB gene. Expression of biologically active human α-1-antitrypsin in transgenic tomato plants with PR1(a signal peptide) led to 1.5 fold higher expression and accumulation of AAT in the transgenic population in contrast to protein expressed with either SPS or modified native signal peptide (Agarwal *et al.*, 2008). Lorito *et al.* (1998) found that endochitinase expression and disease resistance were higher in tobacco transformed with the cDNA sequence of the *T. harzianum* endochitinase gene plus a plant secretion peptide than in plants carrying the same cDNA with the fungal signal peptide. In the present study nucleotide sequence of the sporamin gene of sweet potato encoding a 21 amino acid signal peptide is integrated downstream of the AMV 5'UTR for targeting the chitinase into the apoplastic region. Also accumulation of the chitinase in the apoplastic region enables it to interact with the fungal cell wall prior to penetration into the plant cell membrane. In addition it has been observed that the degraded fungal cell wall fragments activate the host defence mechanisms.

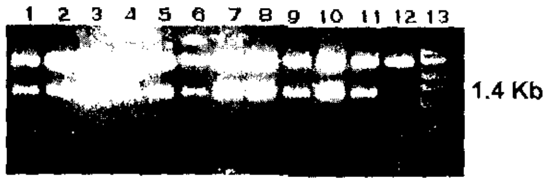
Ribosomal binding efficiency enhancing A-tract of ten Adenine residues was included just upstream of the ATG codon in the signal sequence. The chitinase codon optimized cDNA sequence along with the optimized signal sequence and regulatory elements was analyzed for the presence of restriction enzyme sites and all the sites were eliminated during optimization to facilitate the cloning of the gene by increasing the availability of more restriction enzyme recognition sites. Sal I site was incorporated at the 5' end along with EcoRV at 468 nucleotide positions and EcoRI at the 3' end. The modified sequence was used as the template sequence for designing overlapping primers using Synthetic gene designer to yield 29 primers of 60 nucleotides and one primer of 92 nucleotides in length. Two short external primers with SalI site in the forward primer and EcoRI site in the reverse primer were designed. Although *ThEn 42* gene has been employed for heterologous expression in several crops under the influence of CaMV35 promoter and Nos terminator, expression of optimized gene has not been tested. This is the first report of a fully optimized and modified *ThEn 42* gene for achieving high level heterologous gene expression in castor and other dicots.



Lanes 1-5 : PCR product;

Lane 6 : Supermix DNA ladder

Fig. 1. 1.4 Kb overlap extension PCR product



Restriction digestion with XbaI-BamHI

Lane 1-12 : Putative TA-Chitinase clones;

Lane 13 : Supermix DNA ladder

Fig. 2. Cloning 1.4Kb product into TA vector

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Genome-wide identification and phylogenetic analysis of Dicer-like gene families in castor, *Ricinus communis* L.

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Abstract

Important developmental processes in both plants and animals are partly regulated by genes whose expression is modulated at the post transcriptional level by mechanisms like post-transcriptional gene silencing (PTGS), etc. Dicers, Argonautes and RNA-dependent RNA polymerases form the core components that facilitate gene silencing and have been implicated in the initiation and maintenance of the trigger RNA molecules, central to the process of PTGS. Investigations in eukaryotes have revealed that these proteins are encoded by variable number of genes with plants showing relatively higher number in each gene family. In this study, an *in silico* analysis of castor Dicer-like genes using the EST database and phylogenetic relatedness among them was presented.

Keywords: Castor, PTGS, Dicer, Argonaute, RNA-dependent RNA polymerase

Introduction

Genetic and biochemical evidence has demonstrated that small non-coding RNAs such as microRNAs (miRNAs) and small interfering RNAs (siRNAs) in eukaryotic organisms play important roles in developmental regulation, epigenetic modifications and biotic and abiotic stress responses. These non-coding RNAs, miRNAs and siRNAs, are produced from different types of precursors. These small RNAs are usually generated by the activities of Dicers, Argonautes and RNA-dependent RNA polymerases (RdRPs), which are also sometimes referred to as the core proteins mediating post transcriptional gene silencing (PTGS) (Kapoor *et al.*, 2008). These proteins are involved in the initiation and maintenance of the trigger RNA that is central to this mode of gene regulation. Briefly, initiation of gene silencing involves generation of double stranded RNA (dsRNA) by several mechanisms, for example, bidirectional transcription of DNA, self-complementary RNA foldbacks or RNA-dependent transcription of aberrantly synthesized mRNAs . The complementary dsRNAs are then processed by the RNaseIII-type activities of Dicers into small RNAs, ~19-31 nucleotides in length (siRNA or miRNA). Generally, one strand of these small RNAs then associates with the silencing effector complexes through the Argonaute proteins. This confers sequence-specific guide functions to these complexes that find target mRNAs with sequences complementary to the small RNAs. Silencing/repression of the target genes then occurs by either blocking translation or cleavage of the target mRNA. These small RNAs could also mediate transcriptional gene silencing by recruitment of histone and/or DNA methyltransferases to regulatory sequences of the target genes. Dicer or Dicer-like (DCL) proteins are key components in the miRNA and siRNA biogenesis pathways in processing long double-stranded RNAs into mature small RNAs. In higher plants, insects, protozoa, and some fungi such as *Neurospora crassa* and *Magnaporthe oryzae*, Dicer or DCLs form a small gene family being composed of two, four, or five members, whereas, only one Dicer protein (called DCR) is found in vertebrates, nematodes, *Schizosaccharomyces pombe*, and green alga *Chlamydomonas reinhardtii* (Liu *et al.*, 2009). The idea that a plant might contain multiple Dicer activities was first indicated by the observation of discrete size classes of small RNAs (21- 24bp) (Qi *et al.*, 2005).

Dicer and DCL proteins are large multi-domain ribonucleases (Fig. 1). Vertebrate, insect, and plant DCL proteins generally contain six types of domains including DEAD box, helicase-C, DUF283, PAZ, RNaseIII, and dsRB domains. In lower eukaryotes, one or more of these domains may be absent. The PAZ, RNaseIII, and dsRB domains are considered to function in dsRNA binding and cleavage. The PAZ domain of Dicer is directly connected to the RNaseIIIa domain by a long α helix and can specifically bind the end of dsRNA containing a 3' two-base overhang. In addition, the PAZ domain also plays a role in binding single-stranded RNAs. Dicer functions through intramolecular dimerization of its two RNaseIII domains. The dsRB domain has been suggested to play a role in mediating the processes of discriminating different RNA substrates and the subsequent incorporation of effector complexes. In higher eukaryotes, the DUF283 domain is proposed to be involved in siRNA/miRNA strand selection by recognizing the asymmetry of RNA duplexes directly or by recruiting another dsRB protein. In plants, generally four Dicer-like proteins (DCL1-DCL4) with different roles are found. DCL1 not only is associated with miRNA production but also has a role in the production of small RNAs from endogenous inverted repeats. The other three DCLs are siRNA-generating enzymes (Margis *et al.*, 2006). A detailed in silico analysis of the DCLs in castor using the EST database available is reported here.

Fig. 1. Basic DCL protein structure

Materials and methods

Databases and algorithms used in the survey: *Arabidopsis thaliana* DCL sequences downloaded from the GenBank database were used as query to BLASTn search against the *Ricinus communis* L., genome. DCL protein sequences were aligned using the clustalw platform available at http://www.ebi.ac.uk/Tools/clustalw/. Program InterProScan available online at EMBL-EBI http://www.ebi.ac.uk/Tools/InterProScan/ was employed to detect conserved domains within DCL protein candidates in Ricinus communis L. Multiple sequence alignments and phylogenetic trees were constructed with freely available online tool at NCBI http://www.ncbi.nlm.nih.gov/tools/cobalt/.

Results and discussion

Preliminary analysis of the sequences indicated the presence of four DCLs in castor EST database and these were designated RcoDCL1-4 (*Ricinus communis* DCL1-4). *In silico* analyses of the castor DCLs showed that there were variations among the four homologs of DCLs. Inferred amino acid sequences of the castor DCL were analysed using the InterProScan algorithms. All six domain types were identified and located in most of the castor DCLs. The summary of the analysis about the presence or absence of each of the domains of DCLs is given in table 1. The two most striking results from this analysis were the absence of dsRBb domain in RcoDCL2, 3 and 4 and complete absence of dsRB domain in RcoDCL3. Only Rco DCL1 is having both dsRB domains and it is observed that the second dsRB (dsRBb) domain is completely lacking in non-plant DCRs. RcoDCL2 protein is different from other Dicer-types by their lack of a complete dsRB domain. All the RcoDCLs had the PAZ domain which is not detected in the ciliate, fungal and algal DCRs but detected in all of the plant DCLs. It has been suggested that the absence of a PAZ domain may play an important role in discriminating which accessory protein a Dicer interacts with, there by guiding the recognition of its template. The presence of PAZ domain in all plant Dicer types seems to rule out the notion that its presence or absence dictates the function of a DCL in plants. However, amino acid changes within the domain could be responsible for determining the action of small RNA that they generate, for example by dictating their size.

In *Arabidopsis,* and probably all plants, the four different Dicer types produce small RNAs that play different roles. Each different type requires specificity in recognizing its substrate RNA and the ability to pass the small RNA that it generates to the correct effector complex. Unlike all of the other domains, the dsRBb domain, by its presence, absence or type, is a good candidate for regulating substrate specificity and/or the interaction with associated proteins to direct processed small RNAs to the appropriate effector complex. DCL2, 3 and 4 proteins are different from the other Dicer-types by their lack of a dsRBb domain. There is good evidence that dsRB domains not only bind to dsRNA but also function as protein-protein interaction domains. It has also been shown that fusion DCL proteins containing both dsRBa and dsRBb domains can bind to members of the HY1/DRB family of proteins that are probably associated with small RNA pathways in plants.

Comparison of RcoDCLs with other DCLs: To determine evolutionary relatedness of DCLs from *Arabidopsis*, castor, rice, *poplar, Physcomitrella, Vitis vinifera* and *Brassica*, total protein sequences from these organism s were used to construct a neighbour-joining phylogenetic tree (Fig. 2).

Phylogenetic analysis of different plant DCL protein sequences revealed that these dicot proteins share high sequence similarity with each other. DCL protein sequences clustered into four subgroups based on the type of DCL and in each subgroup the six DCL protein sequences clustered together. It was interesting to note that the RcoDCLs (1-4) clustered tightly with the corresponding DCLs from *Populus trichocarpa*, though castor and Populus belong to different families. Similar associations were also observed when only domains of each DCL proteins were used to construct a phylogenetic tree (data not shown).

Table 1 Locations of domains in castor DCL proteins

Domain Name	Rco DCL1	Rco DCL2	Rco DCL3	Rco DCL4
DExD	121-173	10-117	65-226	128-271
Helicase-C	323-403	318-483	416-571	475-629
Duf283	476-571	504-590	601-691	656-748
PAZ	829-981	752-880	915-1024	955-1054
RNaseIIIa	1001-1163	931-1063	1049-1221	1113-1251
RNaseIIIb	1204-1352	1099-1246	1262-1406	1292-1436
dsRBa	1378-1441	1272-1339		1621-1697
dsRBb	1465-1540			

The linear arrangement of domain typically found in DCL proteins is depicted in the Table 1. The table contains the locations in amino acid residues, where the eight different domains can be found in a DCL molecule. Boxes that have been blacked out represent the absence or failure to detect the presence of the domain in the appropriate DCL

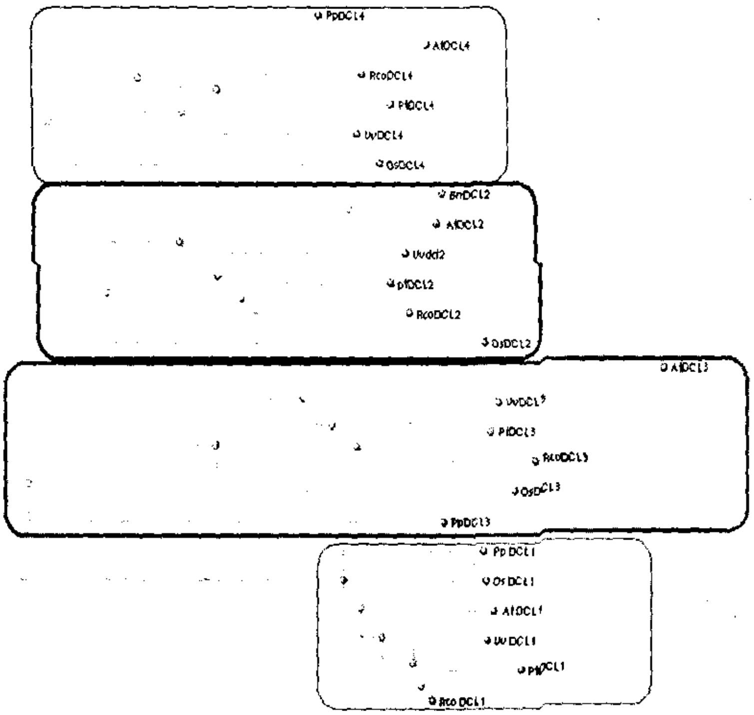

Fig. 2. Phylogenetic analysis of RcoDCL protein sequences with other DCLs.

The genes are named according to the species in which they are found and their DCL type. At: *Arabidopsis thaliana;* Pt: *Populus trichocarpa;* Rco: *Ricinus communis* L; Vv: *Vitis vinifera;* Os: *Oryza sativa;* Pp: *Physcomitrella patens*

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Sources of resistance to *Botrytis ricini* (Godfrey) in castor germplasm

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Abstract

Grey mold caused by *Botrytis ricini* (Godfrey) is one of the yield limiting diseases in castor (*Ricinus communis* L.). Under epidemic condition, it can cause yield loss upto 85%. *Botrytis* is very severe in Andhra Pradesh and Tamil Nadu states of India. Non-genetic measures were not effective in controlling castor grey mold. Breeding resistant cultivars is the only effective way to manage it. All the released cultivars are highly susceptible to grey mold. In order to search resistance sources against *Botrytis,* castor germplasm was screened under epiphytotic conditions in both field and glasshouse over years. Results of multi-year screening and the resistance sources identified are presented in the paper.

Keywords: *Botrytis* grey mold, castor, germplasm, resistance

Introduction

Castor (*Ricinus communis* L.) is an important industrial oilseed crop with world adaptability. Grey mold caused by *Botrytis ricini* (Godfrey) was reported in many castor growing countries. Under epidemic condition, it can cause yield loss upto 85% (Raoof and Nageshwar Rao, 1999). It is a serious recurring problem in Andhra Pradesh and Tamil Nadu states of India. *Botrytis ricini* becomes severe during cyclonic weather and spreads very fast through air-borne conidia during castor flowering and capsule formation stages. The disease spreads upwards in the spikes infecting flowers and developing capsules. It affects capsule development and seed filling. Grey mold on castor appeared first time in an epidemic condition in 1987 in Andhra Pradesh (Moses and Reddy, 1989). Since then it is reoccurring almost every year and causing sever damage. Non-genetic measures failed to control grey mold. Raoof and Mehatab Yasmeen (2006) confirmed host specificity of *B. ricini* to castor. Breeding resistant cultivars is an effective measure to control *Botrytis.* All the existing castor varieties and hybrids are highly susceptible to grey mold. Screening of castor germplasm against *Botrytis* under epiphytotic conditions was undertaken in the present investigation. Differential reaction of germplasm against *Botrytis* and the resistant sources identified are presented in the paper.

Materials and methods

A total of 693 castor germplasm accessions along with susceptible check DCS-9 were screened in batches against grey mold under epiphytotic conditions in the field as well as glasshouse conditions since 2001-02 to 2009-10 at the Directorate of Oilseeds Research, Hyderabad. The accessions which had 0 to 30% infection in the first year were screened again for two more years. Screening of two accessions (RG 2737 and RG 2836) was repeated for six years in the field and glasshouse to confirm consistence of their resistance reaction. *Botrytis* incidence was scored using 0-9 scale, where 0: no incidence, 1:1% of capsule infected, 3: 10% of capsules infected, 5: 11-25% capsules infected, 7: 26-50% capsules infected and 9: >50% capsules infected.

Results and discussion

Differential reaction of castor germplasm against grey mold was observed (Table 1). The infection ranged from 0 to 100%. Reaction of many accessions against *Botrytis* was not consistent. A number of accessions which were found resistant in the first year succumbed to disease in the second year. Fourteen accession exhibited consistent resistant reaction in all three years of testing. Five accessions *viz.*, RG 2787, RG 2836, RG 2980, RG 3126 and RG 3139 had 4.5 to 7.9% infection in first year, 0 to 4% in second year and 0 to10% in third year. One accession (RG 2732) showed 3.8, 3.7 and 16.7% infection in first, second and third year, respectively. Eight accessions exhibited 0 to 28% infection in first year, they continued to show similar reaction in the second (6.7 to 28.3%) and third (4.3 to 30%) year also. Based on consistency of reaction over three years, five accessions were identified as sources of high resistance, one for resistance and eight for moderate resistance (Table 2).

Table 1 Differential reaction of castor germplasm against grey mold

Infection percent	Number of accessions
0-10	25
11-20	132
21-25	65
26-30	39
30-50	199
>50	34

Two accessions *viz.*, RG 2787 and RG 2836 screened over six years, exhibited consistently high resistant reaction both in the field and glasshouse conditions over years. The infection ranged from 0 to 14% in RG 2787 and 0 to 8% in RG 2836 over six years. The susceptible check DCS-9 consistently exhibited 100% infection in all the years under study.

Table 2 sources of resistance to *Botrytis* grey mold in castor germplasm

Accession	Infection (%)	Reaction against *Botrytis*
RG 2787, RG 2836, RG 2980, RG 3126, RG3139	0-10	Highly resistant
RG 2732	16	Resistant
RG 3008, RG 1741, RG 1743, RG 1963, RG 2040, RG 2088, RG 2758, RG 2818	23-30	Moderately ressitant

The resistance sources reported here would of great value in *Botrytis* resistance breeding. These can also be used as base genetic material to develop molecular markers flanked to disease resistant genes as well to study inheritance of *Botrytis* in castor.

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Polymorphic studies in parental lines of castor, *Ricinus communis* L. using EST-SSRs

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Abstract

The present investigation has been undertaken to assess the variation among the six *Ricinus communis* (Castor) parents used for making three crosses for multiple disease resistance, collected from different geographical regions of India. The variation among these parents was characterized using 130 EST-SSR markers. Two EST-SSR markers showed polymorphism with all the six parental line, whereas eight markers showed polymorphism with only four of the parental lines.

Keywords: *Ricinus communis,* parental polymorphism, EST-SSRs

Introduction

Ricinus communis L. (2n = 20), commonly known as castor bean, is an ancient, industrially important non - edible oilseed crop, cultivated through out the world. The genus *Ricinus* is monotypic with communis as the single species. Castor is a member of family *Euphorbiaceae*, it is perennial and predominately cross pollinated crop. It is considered to be native of tropical Africa, and distributed throughout the tropics and subtropics, and is well adapted to the temperate regions (Govaerts *et al.*, 2000). India ranks first in terms of area, production and productivity among the major castor producing countries like China and Brazil.

It has been domesticated for its commercial importance of seeds which is an important source of castor oil, the oil has many industrial uses, which are primarily used in industry (aviation oil), farming (as a source of high-nitrogen fertilizer) and medicine (as a purgative) (Allan *et al.*, 2008). Dehydrated castor oil is used in the paint and varnish industry, manufacture of a wide range of sophisticated products like nylon fibers, jet engine lubricants, hydraulic fluids, plastics, artificial leather, manufacture of fiber optics, bulletproof glass and bone prostheses and as antifreeze for fuels and lubricants utilized in aircraft and space rockets (Ogunniyi, 2006). The annual castor oil production of India reaches to 3.5-4.0 lakh tonnes and approximately 70 % of it is exported to other countries (Damodaram and Hegde, 2007).

With the increasing demand for castor oil, production and productivity of the castor has to be enhanced. Genetic variation among the parents in terms of agronomic traits, disease and pest resistance and other abiotic stresses is an essential criteria used for hybrid and variety development. In the current study polymorphism among the geographically distinct six parental lines were, studied using 130 EST- SSR (Expressed Sequence Tag- Simple Sequence Repeat) markers (supplied by Dr. V. Dinesh Kumar, DOR, Hyderabad).

Materials and Methods

Geographically distinct six parental lines of castor (Supplied by Dr. K. Anjani, DOR) were selected for studying the parental polymorphism, which were used for making three crosses. Genomic DNA was extracted from young tender leaves from a random sample of ten field grown plants from each parent following the standard CTAB method with minor modifications

(Doyle and Doyle, 1990). DNA concentrations were determined using known amount of λ-DNA as standards. PCR optimization and primer survey protocol for the Polymerase Chain Reaction (PCR) was optimized by varying the concentration of template DNA, *Taq* DNA polymerase. One hundred thirty (130) primer pairs (data unpublished) were surved or screened among the six parents for parental polymorphism.

The amplification reaction with the EST-SSR primers was carried out in a final volume of 20 μl in DNA Thermal Cycler (Eppendrof version, 2.0, Germany). Each reaction mixture contained 2.0 μl 10 X reaction buffer containing 1.5mM $MgCl_2$, 1.0 U of *Taq* DNA polymerase; 0.08mM of dNTPs (Bangalore Genei), 5.0 Pmoles of each forward and reverse primer (Synthesized by Biosciences) and approximately 50 ng of template DNA.

The PCR amplification conditions as follows: initial denaturation at 94°C for 5 min followed by 35 cycles of denaturation at 94°C for 1 min, primer annealing at 56°C for 1 min and elongation at 72°C for 1 min, followed by final elongation at 72°C for 10 min. 15 μl of the amplified PCR product from each reaction was separated on 3.5 % agarose gel containing ethidium bromide in 1x TAE at 120 V, finally visualized and photographed using gel documentation (Syngen). Approximately 2 μl of the amplified PCR product was electrophoresed on 6% denaturing Polyacrylamide gel on Sequi-Gen (BioRad, USA) for 2 hrs in 1 X TBE Buffer at 100 W, 50mA at 50°C. The PAGE gel was photographed after drying.

Results and discussion

Parental polymorphism was assessed among the six castor parental lines collected from different geographical regions of India. In the current study out of 130 EST-SSR markers that were, screened 2 EST-SSRs primer pairs showed polymorphism with all the six parents (Fig. 1), whereas 8 EST-SSRs primer pairs showed polymorphism with four of the parents. Eighteen, seventeen, and nineteen EST-SSRs primer pairs showed polymorphism with parental lines used for wilt, *botrytis* and nematode cross respectively.

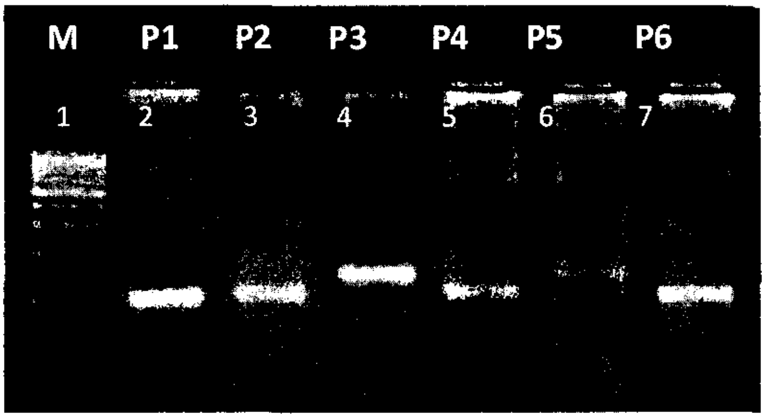

Fig. 1. Parental polymorphism with castor EST-SSR on 3.5% Agarose gel Lane 1 (M) : 100bp Marker; Lane 2-7 : Parental lines

Protein based markers such as peroxidase, esterase Sathaiah and Reddy (1984; 1986) and DNA based markers such as AFLP (Allan *et al.*, 2008), and SSRs (Allan *et al.*, 2008; Bajay, 2010) has been reported for the genetic diversity studies in castor. The above study indicates that EST-SSRs markers can be used to study parental polymorphism and can also be utilized for genetic diversity analysis, association mapping, development of markers and for other applications in castor.

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Generation mean analysis for inheritance of quantitative traits in castor, *Ricinus Communis* L.

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Abstract

The components of gene effect for characters were studied following generation mean analysis by using a set of five basic generations (P_1, P_2, F_2, B_1 and B_2) derived from six genotype. Non-allelic interaction were preponderant for all the characters in majority of cross as evident from individual scaling test and joint scaling test. In days to 50% flowering, additive and dominance gene action was in negative direction, which may be further exploited through pure line. The gene action a x a and d x d type effect observed in effective branches. In length of main spike and number of capsules observed d x d type of gene action. The involvement of both additive and dominance gene action and presence of inter allelic interaction in yield component and wilt incitement indicating that straight selection to improve the traits. Hence, the breeding method like bi-parental mating recurrent selection and reciprocal recurrent selection can be used to utilize both type of gene action to manipulate the trait supervision in the target.

Keywords: Gene effect, generation mean, castor

Introduction

Castor is an important non-edible oilseed crop of arid and semi-arid region of India. It is monoecious in nature favours cross pollination up to the extent of 50%. India is the largest castor producer in the world. The area, production and productivity of crop in India during 2008-09 were 8.70 lakh ha, 10.20 lakh metric tonnes and 1331 kg/ha, respectively. Gujarat shares about 49% of total area and 80 % of the total castor production of the country (Anonymous 2009-10). The five parameter generation mean analysis provides valuable information on the nature of gene action and relative magnitude of additive, dominance and epistasis variances. The analysis of generation mean (Hayman, 1958) is useful in testing the adequacy of different type of genetic models and then estimating the genetic parameters in the form of components of means. The parameters obtained were useful to the breeders in understanding the genetic structure of populations, their variation and response to various breeding approaches. Seed yield is a very complex trait controlled by polygene with small effects. Wilt incidence is a major attribute which limits the castor cultivation and needs urgent attention for improvement. The information of genetic architecture of yield and its various components is, therefore, the prerequisite for adopting a sound breeding programmme with the above in view. The present investigation was conducted to study genetic parameters for yield components, including wilt incidence. This can be used to select the breeding methodology for improvement of the characters under study.

Materials and methods

This study comprising of five families to study gene action derived from five crosses *viz.*, RG-392 x JI-258, RG-392 x DCS-9, RG-390 x RG-724, RG-390 x JI-258 and RG-390 x JI-35. These crosses were selfed and back cross to obtain their F_2, B_1 and B_2 generation. Generation of all these five crosses was studied during rainy season of 2003 at Main Castor-Mustard Research Station, Gujarat Agricultural University, Sardarkrushinagar. The experiment was laid out in a compact family block design with three replications, whereas five generations of each cross represented individual plot within family. The spacing was maintained at 90 cm x 60 cm. Additionally, a set of five family was grown in wilt-sick plot comprising 12 dibbles in P_1, P_2, F_1 and 48 dibbles in F_2, B_1 and B_2. The observations were recorded for eight important characters.

Results and discussion

The analysis of variance for the compact family block design for all the five families indicated that the mean sum of square between families were highly significant for all the traits under study except for number of effective branches/plant, which suggest that all the families differed significantly with respect to their mean performance. Whereas the analysis of variance showed significant differences between all the generations except for days to 50% flowering in cross IV and V, number of capsules in main spike in cross II. The estimates of gene effect for 50% flowering in all the five crosses indicated that additive and dominance x dominance type of non-allelic interaction were also involved in expression of days to flowering. In cross I, II and IV epistasis was observed (Table 1). Additionally, additive and additive x additive type of genetic effects were found to be negative in direction. Which may carry some early transgressives may be further developed in to pure line. Both additive and non-additive type of gene action in the inheritance of this trait which support the present finding. Rabadia (1989) and Patel (1991) also reported non-additive genetic control for this trait. For number of effective branches/plant, the estimates of scaling test indicated that the 'D' test was significant for all the five cross, whereas 'C' test was significant for all the cross except for the cross II. The significant scaling test stated that additive x additive and dominance x dominance type of epistasis interaction were involved. The significant and higher magnitude of 'i' and 'l' type of estimates for all the crosses suggested that digenic interaction of a x a and d x d type were mainly involved in the expression of number of effective branches. Furthermore, the magnitude of epistasis interaction was more indicating the important role of population breeding method to improve the trait. The same results supported by Dobariya *et al.* (1992) and Mehta (2000). In length of main spike, observed significant additive and additive x additive gene effect in all five crosses but the additive effect in crosses II, IV and V and additive x additive gene interaction in all crosses in negative direction. Dominance and dominance x dominance type of gene effects were also found to be significant in all the five families for this trait. Additionally, the direction of dominance gene action was negative but dominance x dominance gene interaction was positive in direction. The estimates of scaling test showed the presence of non-allelic interaction in all the five families for number of capsule. The additive gene action was significant in all crosses where the dominance gene effect were significant in all crosses except cross II. Among the epistasis interactions, additive x additive type of gene interaction was significant in all the crosses except for cross II, but the direction of the estimate was negative in all the five crosses.Which indicating that along with the main gene effects interaction was also operative in decreasing the number of capsule on main spike.The estimates of dominance x dominance (l) gene action were significant in all the cross except for cross II. The crosses I, III and V expressed duplicate epistasis for the trait while cross IV recorded complementary type of gene action which may give superior combination in the form of trasgressive in the later generation. Patel (1991) and Dangaria *et al.* (1993) observed non-additive type of gene action for this trait.

Table 1 Estimate of genetic parameters for different quantitative traits in five crosses of castor

Crosses	Scale		Genetics components				
	C	D	m	d	h	l	j
Days to 50% flowering							
I	5.00**	9.00**	50.33**	-0.83**	-13.33**	-6.83**	5.33**
II	0.00	-3.33**	53.66**	-2 67**	-1.11*	-3.11**	-4.44**
III	-2.00**	-10.00**	58.00**	0.67**	5.33**	5.00**	-10.67**
IV	-8.00**	4.67**	54.00**	2.00**	-6.44**	-0.44	16.89**
V	13.67**	-5.67**	55.33**	-0.50**	1.33**	0.50	10.67
Number of **effectives** branches/plant							
I	9.41**	1.12**	8.46**	-0.64**	1.93**	-0.46*	-11.05
II	0.50	-149**	6.92**	0.85**	2.94**	2.78**	-2.65**
III	-6.78**	-5.07**	6.40**	0.97**	2.66**	4.19**	2.28**
IV	-0.31	-4.09**	7.05**	1.38**	2.30**	5.43**	-5.04**
V	8.02**	4.96**	8.60**	0.26**	-1.14**	-1.43**	-4.09**
Length of main **spike** (cm)							
I	-6.27**	18.99**	45.34**	1.90**	-14.14**	-9.90**	33.69**
II	-2.07**	8.68**	47.22**	0.77**	-7.90**	-4.60**	14.33**
III	-0.39**	15.75**	54.57**	-7.87**	-2.86**	-26.30**	21.52**
IV	-4.65**	20.35**	52.58**	-8.81**	-7.33**	-31.97**	33.33**
V	-5.33**	0.69	48.80**	-8.90**	-3.61**	-19.14**	8.03**
Number of capsules on main spike							
I	4.85**	30.76**	45.97**	7.85**	-6.55**	-4.00**	34.55**
II	-6.41**	-5.46**	42.95**	-1.58*	0.20	0.59	1.27
III	0.21	-7.38**	41.13**	-8.54**	-1.20**	-21.96**	9.54**
IV	-28.57**	4.73**	47.74**	-20.07**	4.43**	-48.05**	44.39**
V	6.97**	-7.67**	46.66**	12.46**	1.71**	-18.64**	-19.52**
Seed yield/plant (g)							
I	-400.00	-87.33**	125.00**	54.67**	128.22**	100.89**	416.89**
II	-102.00	76.00**	143.67**	63.00**	38.00**	159.67**	34.67**
III	-331.00**	63.00**	82.67**	67.50**	-32.67**	37.83**	525.33**
IV	-262.33**	-128.33**	130.00**	10.83**	43.33**	63.50**	178.67**
V	-223.00**	83.67**	149.33**	25.17**	79.78**	68.94**	185.78**
Wilt incidence (%)							
I	18.94**	-6.60**	17.20**	-3.16**	-9.27**	1.24**	-34.06**
II	50.16**	1.92**	29.65**	0.00	33.20**	7.08**	-64.33**
III	-27.33**	-	4.05**	0.00	9.11**	-4.55**	36.44**
IV	-36.99**	6.18**	12.97**	-3.07**	-6.99**	-16.30**	56.50**
V	-90.26**	1.36**	17.61**	-21.28**	13.74**	-58.50**	122.16**

*, ** Significant at 5% and 1% levels, respectively

Cross -I :RG-392 x JI-258; Cross -II : RG-392 x DCS-9; Cross -III : RG-390 x RG-724; Cross -IV : RG-390 x JI-258; Cross -V : RG-390 x JI-35

Particularly for seed yield/plant , the magnitude of additive and dominance gene action was very high for cross I and II and the dominance was predominantly involved in the inheritance of seed yield in cross I, IV and V. Further more, complementary genetic interaction was observed in cross I, II, IV and V whereas duplicate epistasis was observed in cross III. In general, the magnitude of dominance x dominance type of gene action was very high for yield/plant. Thus, the population improvement approach like bi-parental mating and recurrent will be quite effective in the yield improvement of the present material as they make use of both additive and non-additive type of gene effect. Non-additive gene action was reported by Dobariya *et al.* (1993) and Patel *et al.* (1992) and non-additive gene were reported by Mehta (2000) . Which are in accordance with finding obtained in present investigation. Wilt incidence is a major attribute, which limits the castor cultivation and need urgent attention for improvement. In present study, additive gene effect was significant for cross I, IV and V and was in negative direction it was desirable. Dominance gene action was significant for all the crosses but having negative direction in cross I and V. The non-allelic interactions were significant for all families but in cross III, IV and V, it was in negative direction and may prove to be useful for selection of resistant progenies in segregating generation. Malhotra and Vashistha (1993) and Solanki *et al.* (2003) observed dominance gene action for resistance to wilt incidence in castor.

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Study of combining ability for yield and its components in castor, *Ricinus communis* L.

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Abstract

Line x tester analysis using seven females and eight males was carried out to estimate combining ability and nature of gene action in castor (*Ricinus communis* L.) for eight different characters during rainy season of 2008. The analysis of variance for combining ability and the estimates of variance ratio ($\sigma^2 gca/\sigma^2 sca$) revealed that the non-additive gene action was predominantly involved in expression of most of the traits. The hybrids SKP 106 x SKI 166, Geeta x SKI 330, SKP 117 x SKI 192, Geeta x JI 368 and JP 90 x SKI 192 exhibited higher specific combining ability effects in desired direction for seed yield/plant and its attributes. The estimates of *gca* effects indicated that the female parent SKP 120 was good combiner for seed yield and also other important traits. The SKI 329 was good general combiner for length of main raceme and number of capsule on primary raceme with significant positive *gca* for total seed yield.

Keywords: Castor, combining ability, L x T analysis

Introduction

Heterosis by seed yield has been exploited in castor (*Ricinus communis* L.) through development of high yielding hybrids. In order to improve further productivity of castor through hybrid programme, it is essential to identify high combining parental lines and their cross combinations. Therefore, the present study was undertaken. The high combining parents and crosses identified were discussed in the present paper.

Materials and methods

Seven pistillate lines (Geeta, SKP 72, SKP 84, SKP 106, SKP 117, SKP 120 and JP 90) and eight pollinator parents *viz.*, SKI 192, SKI 166, SKI 329, SKI 330, JI 362, JI 368, 37504 and HC 8 ,having sufficient variability for seed yield and other component characters, were crossed in a line x tester mating design. Fifty six hybrids and one standard check, GCH 7 along with 15 parents (7 lines and 8 testers) were evaluated at Main Castor-Mustard Research Station, Sardarkrushinagar

Dantiwada Agricultural University, Sardarkrushinagar during rainy season of 2008. The spacing between row to row was 120 cm and plant to plant within a row was 60 cm. Recommended package of practices (for irrigation condition) were adopted. Each genotype was grown in a single row of 10 plants. Observation were recorded on five randomly selected plants for days to 50% flowering, days to maturity, number of nodes up to primary raceme, effective length of main raceme (cm), number of capsule on main raceme, 100 seed weight (g), oil content and total seed yield/plant.

Results and discussion

The analysis of variance (Table 1) for combining ability exhibited that the mean square due to females were significant for most of all characters except seed yield/plant, 100 seed weight and oil content. Whereas, mean square due to males were significant for days to maturity, number of capsules on primary raceme and 100 seed weight. The mean square due to line x tester interaction were significant for all the characters, which indicates that experimental material possessed considerable variability and that gca and sca were involved in the genetic control of various traits. The gca, sca ratio (σ^2gca/σ^2sca) was less than one for most of the characters except number of nodes on primary raceme and length of primary raceme. This indicates that non-additive components of genetic variance was predominantly involved in the expression of yield and its characters. Similar results were reported by Patel (2005) for seed yield/plant and number of capsules on main raceme, Joshi et al. (2001) for days to flowering; Solanki and Joshi (2000) exhibited non-additive gene action for days to maturity, Kanwal (2002) and Patel (2005) reported the non-additive type of gene action for oil content.

Table 1 Analysis of variance (mean square) for combining ability, estimates of components of variance and their ratios for different characters in castor

Source of variation	d.f.	Days to 50 % flowering	Days to maturity	No. of nodes upto primary raceme	Length of primary raceme	No. of capsules on main raceme	Total seed yield/plant	100 seed weight (g)	Oil content (%)
Females	6	32.738**	30.19**	32.05**	1041.70**	670.43**	1724801.00	11.81	1.19
Males	7	24.958	38.17**	5.15	85.35	706.97**	1694278.00	41.04**	1.30
Females x Males	42	9.306**	10.56**	2.41**	55.72**	191.82**	815141.00**	6.56**	1.71**
Error	55	1.689	1.69	0.21	5.81	6.07	96415.42	0.94	0.27
σ^2gca		1.81	2.16	1.22	37.21	45.38	107556	1.68	0.07
σ^2sca		3.77	4.40	1.07	25.17	91.94	359471	2.70	0.73
σ^2gca/σ^2sca		0.48	0.49	1.14	1.48	0.49	0.30	0.62	0.09

* and ** significant at P=0.05 and P=0.01 levels, respectively

The estimation of gca effects (Table 2) showed that among the female parents, SKP 120 was best general combiner followed by SKP 84 and SKP 106. The line, SKP 120 was a good combiner for days to flowering ,days to maturity, 100 seed weight and total seed yield, The female, SKP 84 was a good general combiner for total seed yield and length of primary raceme, whereas SKP 106 was good general combiner for total seed yield and number of nodes up to primary raceme.

Table 2 Estimates of general combining ability (gca) effects of the parents for various characters in castor

Source of variation	Days to 50 % flowering	Days to maturity	No. of nodes upto primary raceme	Length of primary raceme	No. of capsules on main raceme	Total seed yield/plant	100 seed weight (g)	Oil content (%)
Geeta	1.179**	1.286**	2.388**	-1.202**	9.218**	-90.446*	1.011**	0.172*
SKP 72	0.316**	0.598**	0.013	14.298**	1.255**	-243.259**	-1.099**	0.36**
SKP 84	1.429**	1.161**	0.862**	-0002	-3.932**	340.804**	-0.119	0.029
SKP 106	-0.134	-0.027	-0.487**	5.911**	-0.92*	406.741**	-0.797**	-0.008
SKP 117	0.741**	0.723	0.213**	-5.514**	5.743**	-516.384**	-0.516**	-0.495**
SKP 120	-2.179**	-2.339**	-0.85**	-2.977**	-0.632	165.179**	0.511**	-0.164*
JP 90	1.616	-1.402**	-2.138**	-10514**	-10.732**	-62.634	1.011	0.102
SEm.±	0.33	0.33	0.13	0.58	0.71	77.54	0.27	0.12
SKI 192	-1.33**	-0.009	-0.505**	-4.461**	1.723*	37.188	1.437**	0.264
SKI 166	1.455**	0.491	0.923**	1.211	12.766**	526.106**	0.07	0.083
SKI 329	-0.475	0.277	0.095	1.339*	1.523*	333.259**	-2.196**	-0.037
SKI 330	2.548	-0.938**	-0.605**	-0.932	0.709	-49.598	-2.461**	0.111
JI 362	-1.045**	-0.295	-0.32*	-0.561	-8.277**	-503.527**	-0.598*	-0.304*
JI 368	0.17	-0.795*	-0.648**	-1.932**	-10.105**	195.045*	0497	-0.596**
37504	1.741**	3.063**	0.595**	2.239**	3.352**	-172.098*	2.542**	0.359**
HC 8	1.17**	0.205	0.466**	3.09**	-1.691*	-366.384**	0.708*	0.32
S.Em.±	0.94	0.94	0.37	1.61	1.99	219.32	0.58	0.35

* and ** significant at P=0.05 and P=0.01 levels, respectively

Among the males, JI 368, the early duration male exhibited good combining ability for total seed yield. Other short duration male parents, SKI 192 and JI 362 were good combiners for number of nodes up to primary raceme. SKI 329 was a good general combiner for length of main raceme and number of capsule on primary spike with significant positive *gca* effect for total seed yield. The male 37504 had significant positive *gca* effect for 100 seeds weight, oil content, length of main raceme and number of capsule on primary raceme.

Most promising hybrids having high specific combining ability effects for seed yield are given in table 3. The top hybrid having high *sca* effect for total seed yield, SKP 106 x SKI 166 exhibited significant *sca* effect in desired direction for total seed yield/plant, oil content in seed and number of capsules on primary raceme. The second hybrid, Geeta x SKI 330 had significant *sca* effect in desired direction for total seed yield, days to flowering and days to maturity. Another hybrid having high *sca* effects for total seed yield was SKP 117 x SKI 192, it registered significant *sca* effects in desired direction for days to flowering, days to maturity and number of capsules on primary raceme. The fourth hybrid Geeta x JI 368 having high *sca* effect for total seed yield showed significant sca in desired direction for 100 seed weight. The fifth hybrid having good *sca* effects for total seed yield, days to flowering, days to maturity, 100 seed weight and length of primary raceme was JP 90 x SKI 192.

Estimates of variance due to *gca* and *sca* revealed that non-additive gene actions were involved in the inheritance of all the traits. Under such situation exploitation of hybrid is more useful in future.

Table 3 Sca effect of promising hybrids for various characters

Hybrids	Total seed yield/plant	Days to 50 % flowering	Days to maturity	No. of nodes upto primary raceme	Length of primary raceme	No. of capsules on main raceme	100 seed weight (g)	Oil content (%)
SKP 106 x SKI 166	1148.259**	-0.58	0.116	-0.198	2.589	12.034**	-1.609*	0.832*
Geeta x SKI 330	996.161**	-2.25*	-2.5*	-1.245**	-3.055	-22.546**	-0.906	-1.152**
SKP 117 x SKI 192	982.813**	-2.67**	-2.366*	-0.27	2.586	4.414*	0.292	-0.597
Geeta x JI 368	939.018**	-0.607	-1.143	-1.702**	-3.355*	3.168	2.996**	0.245
JP 90 x SKI 192	707.634**	-3.83**	-4.241**	-1.148**	6.114**	-5.554**	2.313**	0.287

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Phenotypic stability in castor, *Ricinus communis* L.

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Abstract

The phenotypic stability of 54 genotypes of castor (40 hybrids resulted from Line x Tester mating design along with 4 lines and 10 testers) grown in four environments (two dates of sowing and two locations) was studied for seed yield and its attributes. The results revealed that only linear component of G x E interaction was significant for number of effective branches/plant and oil content, while both linear and non-linear components were significant for number of capsules on main raceme, 100 seed weight and shelling outturn with preponderance of linear component, which indicated that prediction of performance would be easy for these traits. For length of main raceme and seed yield/plant, prediction of performance would be difficult as only non-linear component of G x E interaction was significant. Among parents, JI-306 was found to be stable for seed yield/plant, number of capsules on main raceme and 100 seed weight. Eleven hybrids were found to be moderately stable with high seed yield/plant, while three hybrids with high seed yield/plant were responsive to unfavourable/poor environmental conditions (bi<1, S^2di 0). Three hybrids *viz.*, JP-84 x JI-285, JP-84 x SKI-226 and JP-88 x SKI-226 were the best hybrids for stability and could be thoroughly tested over space and time before their exploitation for commercial cultivation.

Keywords: G x E interaction, phenotypic stability, castor

Introduction

Castor (*Ricinus communis* L.) is an important industrial non-edible oilseed crop of India. Country earns valuable foreign exchange by the export of oil and seeds of castor. A phenotype is the final product of interaction between genotype and environment in which it grows. A specific genotype does not exhibit the same phenotype under the varying environments and different genotypes respond differently to a specific environment. This variation arising from the lack of correspondence between the genetic and non-genetic effects is known as genotypes x environment interaction. G x E interactions are generally considered impediment in plant breeding as it baffles the breeders in judging the real potential of a genotype when grown in different environments. The existence of interaction between genotype and environment has been recognized earlier by Fisher and Mackenzie (1923). Several workers considered G x E interaction as linear function of environment and proposed regression of yield of a genotype on the mean yield of all genotypes in each environment to evaluate stability of performance of genotype (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Perkins and Jinks, 1968). In the present investigation, the approach suggested by Eberhart and Russell (1966) has been employed to understand the differential G x E interactions of parents and their hybrids to assess the stability of seed yield and its attributes in castor.

Materials and methods

The experimental material comprised 54 genotypes consisting of 40 F_1 hybrids resulting from a line x tester mating design involving four pistillate lines (JP-65, JP-84, JP-88 and SKP-106) and 10 male parents (JI-257, JI-269, JI-285, JI-300, JI-306, JI-308, SKI-226, SKI-267, DCS-9 and PCS-124). The experimental material was laid out in a randomized block design with three replications in four environments. Environments were created by two different dates of sowing 3^{rd} week of July; 2^{nd} week of August) at two different locations *viz.*, Oilseeds Research Station, JAU, Junagadh and Agricultural Research Station, JAU, Amreli. Each genotype was grown in two rows of 12 plants each with inter and intra row spacing of 90 cm x 60 cm, respectively. The recommended package of practices for irrigated conditions was adopted to raise the healthy crop. The observations were recorded on five randomly selected plants for each entry in each replication and in each environment for seed yield and its components (Table 1). The mean values were subjected to statistical analysis. The stability analysis was done as per Eberhart and Russell (1966).

Results and discussion

Analysis of variance (Table 1) revealed that the mean squares due to genotypes differed significantly for all the characters indicating the presence of variability in the experimental material. Similarly, environments were also differed significantly for all the characters. Variance due to G x E interactions was significant for all the characters indicating the differential response of genotypes in expression of the characters to varying environments.

The partitioning of genotype x environment interactions indicated that only linear component contributed towards the differences in stability of genotypes for number of effective branches per plant and oil content, while a substantial portion of variation was linear for number of capsules on main raceme, 100 seed weight and shelling outturn as compared to non-linear component, reflecting the predictability of the performance of genotypes over environments for these three traits. Only non-linear component was significant for length of main raceme and seed yield per plant indicating that major part of the interaction was absolutely unpredictable. Similar findings were also reported for different characters by Mandal and Dana (1994), Manivel and Hussain (2000), Joshi *et al.* (2002), Solanki and Joshi (2003) and Patel and Pathak (2006).

Phenotypic stability of the genotypes was measured by three parameters *viz.*, mean performance over environments (X), regression coefficient (bi) and deviation from regression (S^2di). Breese (1969) and Paroda and Hayes (1971) emphasized that linear regression should simply be regarded as a measure of response of particular genotype, whereas deviation from regression should be considered as measure of stability. The data showed that as many as 32 genotypes (8 parents and 24 hybrids) were found to be stable for seed yield/plant as they expressed non-significant deviation from regression.

Prediction of performance was not possible for 13 high yielding genotypes (3 parents and 10 hybrids) due to their significant deviation from regression. One parent and 14 hybrids with high seed yield/plant and non-significant deviation from regression are listed in table 2 along with various component traits for which they showed stability. The results revealed that three hybrids *viz.*, JP-84 x JI-285, JP-84 x SKI-267 and JP-88 x JI-257 were found to be stable for unfavourable environments having high seed yield/plant, significant regression coefficient (bi<1) and non-significant deviation from regression. The parent, JI-306 and high yielding stable hybrids were average responsive with non-significant regression coefficient The stable parent, JI-306 also depicted stable performance for number of capsules on main raceme and test weight with high *per se,* near unity regression coefficient ($bi \approx 1$) and least deviation from regression ($S^2di \approx 0$). Among the hybrids, JP-84 x JI-285, JP-84 x SKI-226 and JP-88 x SKI-226 were the three most outstanding stable hybrids for seed yield/plant and could be utilized for boosting the yield of castor seed in specific conditions. In general, most of the hybrids identified as stable for seed yield/plant also showed stability for one or more important component traits like number of effective branches/plant, number of capsules on main raceme, length of main raceme, 100 seed weight, shelling outturn and oil content. This indicated that stability of various component traits might be responsible for the observed stability in various hybrids for seed yield per plant. Hence, chance of selection of stable hybrids for seed yield/plant could be enhanced by selecting for stability of yield components. Grafius (1959) also observed that stability of seed yield might be due to stability of various yield components. The highest yielding hybrid, JP-84 x JI-285 was responsive to unfavourable environments, also exhibited average stability for 100-seed weight, shelling outturn and oil content and below average (bi>1) stability for length of main raceme. Two other high yielding hybrids *viz.*, JP-84 x SKI-226 and JP-88 x SKI-226 are responsive to average environmental conditions. All these hybrids might be commercialized after thorough testing over time and space for increasing the productivity of castor under irrigated condition.

Table 1 Analysis of variance for stability of seed yield and component traits in castor

Source of variation	d.f.	Seed yield/ plant	No. of effective branches/plant	No. of capsules on main spike	Length of main raceme	100 seed weight	Shelling outturn	Oil content
Genotypes (G)	53	5432.93*+	30.96*+	576.37*+	161.29*+	55.39*+	42.65*+	3.81*+
Environments (E)	3	5217.63*+	53.33*+	36.62*+	128.24*+	11.29*+	30.09*+	11.67*+
G x E	159	822.96*	0.66*+	26.06*+	7.86*	0.67*+	2.31*+	0.35*+
E + (G x E)	162	904.34*	1.64*+	26.26*+	10.09*	0.87*+	2.82*+	0.56*+
Environment (Linear)	1	15652.8*+9	159.98*+	109.86*+	384.72*+	33.88*+	90.28*+	35.00*+
G x E (Linear)	53	288.05	1.51*+	55.87*+	5.39	1.06*+	3.92*+	0.94*+
Pooled deviation	108	1070.22*	0.23	10.95*	8.93*	0.47*	1.47*	0.05
Pooled error	424	308.723	0.240	4.716	5.168	0.355	0.831	0.105

* Significant against pooled error at 5 % level of probability
\+ Significant against pooled deviation at 5 % level of probability

Table 2 Stable parents and hybrids for seed yield and component traits in castor

Genotypes	Seed yield/plant (g)			Component traits showing stability
	Mean	bi	S^2di	
Parent				
JI-306	175.33	-0.31	38.93	CR, TW
Hybrids				
JP-84 x JI-285	239.42	0.52*	-294.08	LR*, TW, S, O
JP-84 x SKI-226	224.50	1.07	-290.73	S
JP-88 x SKI-226	219.33	1.15	-304.40	EB, CR+, LR, S, O
SKP-106 x JI-300	199.25	1.00	-239.28	CR, S*, O
JP-65 x JI-306	198.08	2.90	49.09	LR*, TW, O
JP-84 x JI-257	193.00	1.96	-105.94	CR*, TW, O+
JP-84 x SKI-267	189.92	-0.23*	-290.31	CR*, LR+, S, O+
SKP-106 x PCS-124	189.08	1.23	-204.94	CR*, S
JP-88 x PCS-124	187.17	1.25	179.94	EB, O+
JP-84 x DCS-9	184.67	0.57	-139.19	O*
JP-65 x SKI-267	177.17	0.68	-95.77	CR*, LR, TW, S*
SKP-106 x SKI-267	176.58	-0.59	499.81	CR*, LR, S, O
JP-88 x JI-257	176.50	0.63*	-302.75	LR, TW, O*
JP-65 x DCS-9	170.67	0.97	-242.29	CR, LR*, TW+, S

*, + indicate stability for favourable and unfavourable environments, respectively
EB = Number of effective branches/plant; CR = Number of capsules on main raceme; LR = Length of main raceme (cm); TW= 100-seed weight (g); S = Shelling outturn (%); O = Oil content (%)

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In vitro regeneration of castor plant from apical meristem

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Abstract

An efficient plant regeneration protocol was described for castor (*Ricinus communis* L.) using meristem as explant. Apical meristems were excised from 5 to 7 days old *in vitro* grown seedlings and cultured on Murashige and Skoog (MS) medium supplemented with different concentrations of cytokinins singly or in combination. Kinetin had marked effect on shoot initiation and shoot quality. Kinetin (0.5 mg/l) in combination with BAP (0.25 mg/l) produced maximum number of shoot (13.3) and shoot length (5.1 cm). For root induction, *in vitro* produced shoots were transferred to rooting media containing ½ MS basal media. Regenerated plantlets were acclimatized successfully.

Keywords: *In vitro*, apical meristem, castor, Kin, BAP

Introduction

Castor (*Ricinus communis* L.) belonging to the family *Euphorbiaceae* is one of the industrially important oilseed crop (Kumari *et al.*, 2008). It is a semi-tropical perennial non-edible oilseed crop, widely cultivated throughout tropical regions. The seeds contain approximately 40 to 60% oil and are the only commercial source of ricinoleic acid used in industrial lubricants, paints, coatings, and plastics (Caupin, 1997). India is the largest producer of castor oil, representing 60% of the global production followed by China and Brazil (FAO, 2006). Genetic engineering is one of the important tools for the improvement of cultivars of this species to lower the toxicity of seed meal due to the availability of the toxic ricinoleic derivatives. The success of using transgenic approach largely depends on an efficient *in vitro* regeneration system, which is rapid, reproducible and applicable to a abroad range of genotypes. However, castor is extremely recalcitrant to *in vitro* regeneration (Ahn *et al.*, 2007). Therefore, it is necessary to develop an efficient regeneration protocol by a range of different techniques which would widen the possibilities for developing transgenic lines and multiplication of improved varieties.

Materials and methods

Plant materials and culture media and conditions: Seed of fusarium wilt resistant line SKP 84 was obtained from the Castor-Mustard Research station, Sardarkrushinagar Dantiwada Agricultural University, Gujarat. Seeds were decoated and surface sterilized in 0.1% (w/v) mercuric chloride for 4 min followed by 4 and 5 times rinsing in sterile deionized water. Four to five seeds were placed in each glass bottle containing basal MS medium (Murashige and Skoog, 1962) and incubated in the light condition for germination. After 7 to 8 days, the apical meristem was excised using sterile surgical blades and placed on basal MS media supplemented with various concentration alone and combination of BAP (6-benzylamino pyrine), Kin and TDZ (Thidiazuront). Cultures were maintained by periodic subculturing on fresh medium once every 15 to 18 days. When the regenerated shoots were attained a height of 4 to 5 cm, adventitious shoots were excised and transferred to rooting media. In all cases, 3% sucrose (w/v) was used as a carbon source. After adjusting the pH to 5.76±0.01 prior to gelling with 0.8% agar (w/v) (Himedia, India), media were sterilized by autoclaving at 121°C for 15 mts. Cultures were maintained in a growth chamber at 27±1°C under a 16/8h (light/dark) photoperiod supplied by cool - white fluorescent lamps.

Plantlets with a well developed root system were washed carefully to remove agar and then transferred to the pots containing red soil, sand and coco peat (1:1:1). After watering, plantlets were maintained in a growth chamber at 27±1°C under 16/8- h (light/dark) photoperiod with fluorescent lamp. After 30 days, these were kept under green house under shade for 4 weeks and then placed outdoors under full sunlight. Entire experiment was repeated twice.

Results and discussion

The present findings demonstrated the possibility for mass propagation of castor through apical meristem. For successful micropropagation apical meristem cultures are preferred as pre-existing meristem easily develop into shoots while maintaining genetic integrity. About 80% of the incubated seeds were germinated in the MS-basal medium (Fig. 1a). Excised apical meristem of 7 to 8 day old seedlings were cultured on MS-medium supplemented with various concentrations of BAP, TDZ and Kinetin in single as well as combination for shoot regeneration. Varied response with respect to shoot length and number of shoot buds was observed (Table 1).

Cytokinins are classified into two major groups by their chemical structures synthetic phenylurea derivates, and adenine derivates, which may occur naturally. Among different types of cytokinin adenine derivatives showed better result. Although phenylurea derivative thiadizuron found to be effective in several plants in this study, TDZ prompted vigorous callus formation even at low concentration. Within four week of culture, all the explants cultured were surrounded by profuse callus.

Among different cytokinins, BAP showed best result for establishment and number of shoot regeneration at lower concentration (0.50 mg/l) with 86.7% established plants but the number of shoots was highest in media supplemented with 0.25 mg/l BAP (7.8) (Fig. 1b). Superiority of BAP in inducing shoot has been earlier reported in castor by various workers independently (Sujatha and Reddy, 1998; Alam *et al.*, 2010). But the concentration they used was found to be deleterious in present investigation. Increase in concentration of BAP above 0.50 mg/l resulted in to poor shoot quality and low multiplication rate (Table 1). Hu and wang (1983) reported that higher concentration of cytokinin reduced the number of micropropagated shoots.

Kinetin consistently gave higher rate of establishment and multiplication as well as shoot length. On visible observation, the quality of kinetin derived shoot was superior as compared to BAP which gave longer petiolated leave (Fig. 1c). Role of kinetin in shoot elongation and quality of shoot in castor was also observed by Alam *et al.* (2010) and Sujatha and Reddy (1998).

The choice of cytokinin and its threshold concentration required to induce the optimal response in different parameters (percentage of shoot formation, mean number of shoots and shoot length) differed. Hence, a combination of cytokinins was used to improve the shoot multiplication rate, percentage of explants forming shoots and shoot length (Table 2). The combination of two cytokinins gave better results as compared to alone in all the treatments tested. The maximum number of shoot (13.3) and shoot length (5.1 cm) obtained in the combination of 0.25 mg/l BAP + 0.5 mg/l Kin (Fig. 1d). The quality of plants were also found to be better than the results depicted by single cytokinin.

Rooting and acclimatization: Induction of rooting is an important step for in vitro plant propagation. Production of plantlets with profuse rooting *in vitro* is important for successful establishment of regenerated plants in soil. Excised shoots were inoculated on ½ MS-basal medium for proper root development with 65% success. Root induction was strengthened within 4 weeks of culture (Fig. 1e). Initially effort made to incorporate auxin for rooting, but even a meager amount of auxin resulted into basal callusing and disruption in growth of shoot. Ahn *et al.* (2007) observed two different rooting patterns using IBA and NAA. Although Sujatha and Reddy (1998) obtained highest rooting with least callusing using 1.0 mg/l IBA, present investigation indicated no need of exogenous supply of auxin, since better rooting could obtained in ½ MS-basal media. Rooting of two Salvia species can be achieved in the absence of auxin (Cuenca and Amo-Marco, 2000). This differential requirement for auxin may be due, in part, to the level of endogenous auxin in cultured shoots.

Fig. 1. *In vitro* regeneration of castor from apical meristem.
a) Shoot multiplication, b) Elongation c)Rooting d) Acclimatization

Plantlets with four to five fully expanded leaves and well-developed roots were successfully acclimatized in the greenhouse, in pots containing red soil, sand and coco peat (1:1:1). About 55% of the micropropagated plants survived and showed normal growth and morphological characteristics (Fig. 1f). This report can be very valuable for transgenic plant development and mass propagation from apical meristem of castor plant.

Acknowledgement: We are thankful to Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Gujarat, for providing seed material to carry out experiment.

Table 1 Effect of different concentrations of BAP, Kinetin and TDZ for multiple shoot regeneration through apical meristem

PGR (BAP + Kin + TDZ) (mg/l)	Frequency	Mean number of shoot and SE±	Mean length (cm) and SE±
BAP			
0.25	70.8	7.8+0.4	2.1+ 0.1
0.50	86.7	3.8+0.8	3.0+0.2
1.00	62.5	4.3+0.4	1.9+0.2
1.50	55.0	5.5+.05	2.1+0.4
2.00	56.7	4.0+0.5	2.0+0.2
TDZ			
0.25	51.7	2.5+0.5	1.6+0.3
0.50	44.2	2.5+0.5	2.0+0.2
1.00	41.7	2.8+0.8	1.6+0.2
1.50	33.3	2.8+0.4	1.7+0.1
2.00	33.3	3.3+0.8	1.2+0.1
KIN			
0.25	66.7	6.0+0.5	2.2+0.2
0.50	75.0	6.8+0.8	3.2+0.2
1.00	66.7	4.0+0.5	2.3+0.2
1.50	57.5	4.3+0.4	2.1+0.1
2.00	62.3	4.0+0.5	2.1+0.1

Data were recorded after 3 weeks of inoculation; PGR = Plant Growth Regulator

Table 2 Effect of combination of BAP and Kinetin for multiple shoot regeneration through apical meristem

PGR(BAP+KIN) (mg/l)	Frequency	Mean number of shoot and SE±	Mean length(cm) and SE±
0.25+0.25	65.8	8.3+0.9	3.4+0.5
0.25+0.50	73.3	13.3+0.8	5.1+0.5
0.25+1.00	60.8	7.8+0.8	2.8+0.4
0.50+0.25	58.3	6.5+0.5	2.5+0.3
0.50+0.50	58.3	8.0+0.5	2.3+0.1
0.50+1.00	49.2	7.8+0.9	2.9+0.2

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Heterosis for seed yield and its component traits in castor, *Ricinus communis* L.

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Abstract

Forty eight hybrids of castor (*Ricinus communis* L.) derived from six pistillate lines and eight inbred lines were evaluated for yield and component traits. Data were analyzed for heterosis. Significant heterotic crosses for the characters under study indicated the presence of genetic diversity among parental lines. Number of crosses exhibiting significant heterobeltiosis and standard heterosis for seed yield were 23 and 1, respectively. The significant positive standard heterosis over GCH-7 for seed yield/plant was exhibited by JP-93 x JI-379 (20%). It also exhibited high heterosis and per se performance for yield attributing traits *viz.*, length of primary spike, number of capsules on primary spike, number of effective branches and 100 seed weight.

Keywords: Castor, heterobeltiosis, standard heterosis, seed yield, yield components

Introduction

Heterosis is of direct relevance for developing hybrids in cross pollinated crops. The exploitation of hybrid vigour in castor on commercial scale has become feasible and economical due to availability of pistillate lines enabling hybrid seed production on large scale. The identification of specific parental combination capable of producing the desired level of F_1 heterotic effect is important in improving the yield potential of this crop. Commercial exploitation of heterosis is considered to be an outstanding application of the principles of genetics into the field of plant breeding. Thus, heterosis can be useful only with marked superiority over the best checks. The present study was, therefore, undertaken to determine the extent of heterosis in castor and to identify most heterotic hybrids.

Materials and methods

The experimental material consisted of 63 entries, comprising of six lines, eight testers and resultant forty eight hybrids produced by line x tester mating design were evaluated along with one standard hybrid GCH-7 as check. The experimental material was sown in a randomized block design with three replications during rainy season of 2009. A single row of 6.0 m length was assigned to each genotype with 10 dibbles having 60 cm intra-row spacing and 120 cm inter-row spacing. Five plants were randomly selected from each replication for each genotype and the average value/plot was computed for recording observations on plant height, number of nodes up to the primary spike, length of the primary spike (cm), number of capsules on primary spike, number of effective branches/plant, total number of branches/plant, 100 seed weight (g), seed yield/plant (g) and oil content. While days to 50% flowering and days to 50% maturity were recorded on plot basis. Magnitude of heterosis and heterobeltiosis were computed as per procedure suggested by Meredith and Bridge (1972) and Fonesca and Patterson (1968), respectively.

Results and discussion

Pooled analysis of variance revealed that the mean squares due to genotypes were significant for all the characters under study. Mean squares due to genotypes were further partitioned into mean squares due to parents, hybrids, parents vs. hybrids and check vs. hybrids. The parents and hybrids differed significantly for all the characters. This revealed the existence of considerable genetic variability among the parents and hybrids for all the characters under study (Table 1). The analysis of variance further revealed that hybrids differed significantly for all the characters. The mean square due to parents vs. hybrids were significant for most of the traits except for number of capsules on primary spike, number of effective branches/plant and total number of branches/plant thereby suggesting presence of substantial amount of heterosis in crosses for most of the characters.

The perusal of data on performance of hybrids with respect to heterosis over better parent revealed that 23 hybrids manifested significant positive heterosis over their better parents for seed yield/plant. The highest magnitude of heterobeltiosis for seed yield/plant was exhibited by the hybrid VP-1 x JI-379 (165%). It was observed that hybrids showing high heterobeltiosis for seed yield/plant in general also manifested heterotic effects for its contributing characters like length of main spike, number of capsules on primary spike, number of effective branches/plant and 100 seed weight (Table 2). This study thus substantiates the findings of Kaul and Prasad (1983) and Mehta *et al.* (1991).

Improvement in yield is one of the important objectives, so the superiority of hybrids over best cultivated hybrid is essential for increasing its commercial value. In the present study, well known hybrid GCH-7 was used as standard check hybrid in order to obtain information on superiority of hybrids. The highest yielding hybrid JP-93 x JI-379 had the highest standard heterosis (20%) over the best check GCH-7. The hybrid JP-93 x JI-379 exhibited maximum seed yield (338 g) and highest standard heterosis (20%) for seed yield over the check GCH-7. In addition to this, the hybrid JP-93 x JI-379 also exhibited significant amount of heterosis over better parent (61%) for seed yield (Table 2). Several workers have also reported the presence of considerable degree of heterosis for seed yield/plant in castor Joshi *et al.* (2001), Lavanya and Chandramohan (2003) and Patel and Pathak (2006). With respect to yield contributing traits *viz.*, length of primary spike, number of capsules on primary spike, number of effective branches/plant and 100 seed weight, hybrids JP-93 x JI-379, SKP 84 x JI 244 were found promising as they exhibited positive heterosis over GCH-7. Thus, high degree of heterosis for seed yield might be attributed to the heterosis for these component characters. Whitehouse *et al.* (1958) and Graffius (1956) have suggested that there cannot be any gene system for seed yield *per se*, as yield is an end product of the multiplicative interaction of several yield components.

Further, the above mentioned promising hybrids exhibited significant negative standard heterosis for days to 50% flowering thereby suggesting that high yield in hybrids can be achieved along with early maturity. Thus, considerable amount of heterobeltiosis and standard heterosis observed for seed yield and other associated characters suggested the presence of large genetic diversity among the males and the females and presence of high heterotic potential in the present material. *Availability of stable pistillate lines and large scale of hybrid production technology in castor, commercial exploitation of* heterosis is feasible and economical. However, the stability performance of hybrids across the environments is essential for making their commercial cultivation beneficial.

Table 1 Analysis of variance (mean squares) for yield and its components

Source	D.F.	Days to 50% flowering	Days to 50% maturity	Plant height	No. of nodes upto primary spike	Length of primary spike	No. of capsules on primary spike	No. of effective branches/plant	Total number of branches/ plant	100 seed weight	Seed yield/plant	Oil content
Replications	2	1.17	5.69	37.37	0.11	0.10	9.88	1.55	1.80	0.38	53.24	0.01
Genotypes	63	185.50**	448.62**	1667.60**	14.49**	413.31**	1399.48**	34.72**	39.62**	26.48**	14708.70**	6.54**
Parents	13	185.50**	474.56**	4134.54**	15.84**	416.43**	3748.51**	39.33**	33.61**	46.81**	15365.83**	6.16**
Lines	5	206.13**	476.18**	2439.92**	12.40**	291.13**	1057.95**	8.65**	12.92**	41.48**	25493.86**	1.03**
Testers	7	180.52**	537.57**	3643.67**	18.56**	557.30**	5906.97**	14.64**	18.52**	57.30**	7660.41**	5.27**
Lines vs Testers	1	117.16**	25.33	16043.73**	14.00**	56.80**	2092.05**	365.50**	242.78**	19.53**	18663.69**	38.07**
Hybrids	47	162.19**	396.04**	1078.76**	14.41**	402.86**	813.47**	35.43**	43.60**	20.00**	11440.36**	6.13**
Parents vs hybrids	1	1221.85**	1654.34**	164.28*	11.07**	1650.59**	71.13	2.47	1.39	61.90**	156498.40**	28.37**
Error	126	1.17	15.09	33.02	0.19	6.94	74.44	1.83	2.06	0.88	685.79	0.24

*, ** *Significant at 5 % and 1 % levels of probability, respectively.*

Table 2 Promising crosses for seed yield/plant with heterosis over standard check hybrid, GCH-7 and better parent and *component traits showing significant standard heterosis in castor*

Promising hybrids	Seed yield (g)	Standard heterosis	Better parent Heterosis	Component traits showing significant standard heterosis over GCH-7
JP 93 x JI 379	338.47	20.48**	61.69**	DF, PH, ND, LS, C, EB, SW
SKP 84 x JI 244	319.27	13.65	50.03**	DF, PH, LS, SW
JP 93 x JI 244	309.20	10.06	45.30**	DF, DM, PH, ND, EB
JP 84 x JI 338	295.47	5.18	17.28**	DF, ND, EB, TB, SW
JP 93 x SKI 147	295.13	5.05	40.99**	DF, ND, LS, C
VP 1 x JI 338	290.67	3.47	30.39**	DF, DM, ND, LS, C, EB, OC
SKP 84 x JI 381	287.47	2.33	49.78**	DF, DM, LS, C
JP 93 x JI 338	281.27	0.12	26.17**	DF, DM, PH,ND, C
GCH 7 (Standard check)	280.93	-	-	-
SEm±	21.18	21.18	21.18	-

*, ** Significant at 5 % and 1 % levels of probability, respectively; DF- Days to 50% flowering; LS- Length of primary spike; DM- Days to 50% maturity; C- Number of capsules on primary spike; PH- Plant height; SW- Seed weight; ND-Number of nodes up to primary spike; OC-Oil content; TB- Total number of branches/plant; EB- Number of effective branches/plant

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High yielding and wilt resistant castor variety GC-3 for irrigated areas of Gujarat

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Abstract

GC-2, a wilt resistant castor (*Ricinus communis* L.) variety yielded 2 to 34% higher than high yielding checks over locations and year. It exhibited high resistance to *Fusarium* wilt (5.3% wilt incidence). It was recommended for cultivation in Gujarat state under irrigated conditions.

Keywords: Castor, wilt, resistance, variety, yield

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop grown in various countries throughout the world. Castor oil is used for number of industrial products. During the year 2008-09, the area under castor crop in India was 8.70 lakh ha, which contributed 10.20 lakh metric t production with a productivity of 1331 kg/ha. Gujarat is the leading state in the country with respect to area, production and productivity of castor, covering area of 4.34 lakh ha with the production of 8.52 lakh t and average productivity of 1963 kg/ha. In castor, the most important disease is Fusarium wilt. This disease is now becoming a serious problem especially in the Gujarat, where continuous castor cultivation is common practice. The reported yield loss due to wilt was upto 77%. Another important disease prevailing in the Saurashtra region is the *Macrophomina* root rot. The best option for management of the disease in castor is the resistance breeding. Development of high yielding and resistance to diseases varieties/hybrids provides better alternate to existing cultivating varieties/ hybrids.

Materials and methods

As a result of castor breeding work at Main Oilseeds Research Station, Junagadh, an inbred *viz.*, JI-273 was developed through hybridization followed by pedigree method of selection from a three-way cross [(JP-65 x JI-88) x 48-1]. The cross was effected in the year 1991-92 and the resulting inbred was tested during 1998-99 to 2004-05 in multilocation trials at state level and during 2001-02 to 2003-04 in different AICRP trials at all India level.

Results and discussion

The experimental results indicated that, from 31 testing trials, the variety GC-3 on an average produced 2340 kg/ha seeds, which was 30.5% higher than the check variety GC-2 (1794 kg/ha). While comparing with four checks *viz.*, GC-2, GCH-4, GCH-5 and GCH-6 based on 21 testing trials, the variety GC-3 (2316 kg/ha) gave 34.2% and 8.1% higher seed yield than GC-2 and GCH-4, respectively. In 18 irrigated trials, the variety GC-3 (2336 kg/ha) gave 31.1, 9.4, 2.3 and 10.3% higher seed yield than GC-2, GCH-4, GCH-5 and GCH-6, respectively. In 10 trials, the variety GC-3 (2393 kg/ha) gave 23.5%, 9.8% and 14.9% higher seed yield than GC-2, 48-1 and DCS-9, respectively.

Table 1 Mean performance of castor variety GC-3 (1998-99 to 2004-05)

No. of locations	Seed yield of GC-3 (JI-273) (kg/ha)	Checks	Seed yield (kg/ha)	Per cent increase over check
31	2340	GC-2	1794	30.47
21	2316	GC-2	1726	34.17
		GCH-4	2142	8.13
18	2336	GC-2	1781	31.14
		GCH-4	2135	9.42
		GCH-5	2284	2.25
		GCH-6	2117	10.33
10	2393	GC-2	1937	23.54
		48-1	2178	9.84
		DCS-9	2081	14.97

GC-3 was found to be highly resistant to *Fusarium* wilt than all the checks in wilt sick plot at S.K.Nagar. Oil content in GC-3 was higher (49.7%) than GC-2, GCH-4, GCH-5 and GCH-6, while 100 seed weight (29.6 g) of GC-3 was higher than GC-2 and GCH-4, where as other yield attributing characters were found at par with checks. GC-3 was recommended for commercial cultivation in castor growing areas of Gujarat state under irrigated condition by 3rd Combined Joint Agresco meeting held on 12 to 14, April 2007 at Anand Agricultural University, Anand and also recommended by 36th State seed *sub-committee meeting.*

Table 2 Reaction of GC-2 and checks against *Fusarium* wilt and their agronomic and economic attributes

Entry	Wilt reaction in sick plot (%)	100 seed weight (g)	Oil content (%)	No. of nodes to primary raceme	Length of main spike (cm)	Effective Spike/plant	Plant height up to main spike (cm)	Days to maturity of main spike
GC-3	5.3	29.64	49.67	16	46	9	110	103
GC-2 (C)	80.6	25.94	47.88	14	43	7	109	99
GCH-4 (C)	88.5	27.65	47.59	14	47	9	103	97
GCH-5 (C)	86.2	29.95	48.23	16	53	9	118	105
GCH-6 (C)	72.6	32.33	45.44	14	50	9	95	96

C = Check

Genetic analysis of plant stature, oil content, earliness and yield components in castor, *Ricinus communis* L.

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Abstract

The genetic analysis was done through Line x Tester design involving 5 pistillate lines and 14 pollen parents for the development of a set of 70 hybrids. The preponderance of additive gene action was observed for the control of days to 50% flowering and days to 50% maturity of main raceme as well as number of nodes up to main raceme. For plant height and oil content, non-additive gene effect was propounded. The parents, SKP-8, 103745, 1379, SKP-93, TMV-5, Aruna, SH-72 and SK2-8A were good general combiners for imparting earliness, former three and VP-1 were good general combiners for short plant stature, whereas later two and SKP-82, JH-128, SH-41 and 48-1 were good general combiners for oil content. The good specific cross combinations for yield were SKP-8 x TMV-5, VP-I x SKI-41 and SKP 25 x 1379. They were also identified as superior hybrids for earliness, high oil content and short plant stature, respectively. Hence, these may be directly exploited for commercial cultivation.

Keywords: Castor, combining ability, plant Stature, oil content and yield

Introduction

Heterosis breeding is the major breeding approach for castor crop in present era. However, the extent of success in improving one or more economic characters depends on the judicious selection of parents and subsequent handling of segregating generations. Line x Tester analysis helps in testing of a large number of genotypes at a time. Thus, present investigation was undertaken to study the combing ability for identification of good combiners and promising crosses for future better accomplishment in castor.

Materials and methods

The experimental material was comprised of 70 F_1 hybrids developed through Line x Tester mating using five pistilate lines and 14 pollen parents. All the hybrids were evaluated along with parents in randomized block design with four replications. Each entry was represented by single row accommodating 16 plants at 90 cm x 60 cm plant geometry. Ten randomly selected plants from each entry were used for recording various observations. Statistical analysis was subjected as per Kempthrone (1957).

Results and discussion

The analysis of variance for combining ability (Table 1) revealed that the variance due to females, males and hybrids were significant for all the characters except variance due to female for oil content, which suggest that the females, males and hybrids differed statistically among themselves. The contrast comparisons due to parent vs. hybrid were also significant for all the attributes indicating the presence of heterotic effects.

Both the components of genetic variance were significant for all the character revealing importance of both additive and non-additive genetic variances. However, the large estimates of variance due to general combining ability (*gca*) for days to 50% flowering, days to 50% maturity and number of nodes up to the main raceme suggested preponderance of additive genetic variance. However, for the plant height, both the components were of equal importance. For oil content and seed yield, the variance due to specific combining ability (*sca*) was of larger magnitude indicating greater influence of non-additive genetic variance for the inheritance of these traits. The results are in conformity with reports of Singh and Yadava (1981), Ramu *et al.* (2002), Lavanya and Mohan (2003) and Patel *el al.* (2003).

The estimates of *gca* effects (Table 2) revealed that the females parent SKP-93 and SKP-8 were good general combiners for days to 50% flowering as well as days to 50% maturity of main raceme and seed yield. Likewise, lines SKP-25 and SKP-82 were good general combiners for oil content' and VP-I for plant height.

Table 1 Analysis of variance for combining ability and variance components in castor

Source	d.f.	Days to 50% flowering of main raceme	Days to 50% maturity of main raceme	Number of nodes up to main raceme	Plant height	Oil content	Seed yield/plant
Replication/season	6	7.10	31.64	15.34	22.8	0.54	149.09
Parents	18	368.20 **	3094.96**	40.94	150.9**	4.67**	11018.40**
L (Females)	4	210.78 **	1631.53**	7.62**	58.59**	6.04	12963.34**
T (Males)	13	423.54 **	3678.59**	48.80**	158.9**	4.04*	5590.32**
L x T	1	278.37**	1361.50**	72.01**	511.19**	7.42**	74883.75**
Hybrids	69	248.72**	1227.19**	37.48**	544.2**	5.03**	8749.33**
Parents vs **Hybrids**	1	50.88 **	2277.75**	7.87**	277.2**	52.8**	72987.75**
Error	528	2.78	5.13	1.77	15.94	0.16	67.86
Variance components							
$\sigma^2 gca$		9.15	37.77	1.74	17.81	0.10	321.86
$\sigma^2 sca$		1.99	28.05	0.55	17.90	0.90	540.99
$2\sigma^2 gca/2\sigma^2 sca$		0.22	0.74	0.32	1.01	3.03	1.68

*=5% level of probability; **=1% level of probability

Table 2 General combining ability effects of parents for different characters in castor

Parents	Days to 50% flowering of main raceme	Days to 50% maturity of main raceme	Number of nodes up to main raceme	Plant height	Oil content	Seed yield/plant
Females						
SKP-8	-1.30**	-2.48**	-1.85**	-0.97	-0.37**	-14.85**
SKP-25	-1.26**	1.34**	-0.50**	0.47	0.42**	-16.93**
SKP-82	3.08**	6.30**	1.32**	-5.31**	0.62**	16.04**
SKP-93	-1.12 **	-5.72**	0.58**	0.52	0.08**	30.73**
VP-1	0.61**	0.57**	0.45**	5.33**	0.39**	-15.00**
SE (95) ±	0.12	0.17	0.10	0.55	0.03	0.62
Males						
JH-128	2.51**	1.34**	0.15	-0.79**	0.19**	5.61**
JI-77	7.06**	15.19**	1.08**	2.23**	-0.50**	9.28**
SH-66	-0.16**	3.43**	0.72**	10.55**	0.46**	24.73**
SH-72	2.56**	-2.39**	0.10	-1.91**	-0.19**	1.81
SKI-41	-2.09**	-6.33**	0.14	5.13**	0.42**	-16.57**
SK2-41	-0.51**	0.89**	1.27**	-4.22**	0.11*	-12.99**
SA-2	-2.24**	-4.78	0.24	4.54**	0.35**	-17.32**
48-1	-1.71 **	-0.61*	0.66**	-2.02**	-0.09*	-12.17**
TMV-5	7.56 **	-9.29**	1.16**	5.29**	0.13**	16.98**
SPS-35-9B	-0.74**	-3.38**	0.58**	0.12	0.07	-23.89**
103745	-8.31**	-14.33**	-3.73**	-12.86**	-0.30**	-5.74**
1379	-9.14**	-17.36**	-4.14**	-11.13**	-0.37**	2.68**
Aruna	-2.34**	-4.36**	1.06**	3.43**	-0.08	15.46**
SE (gi) ±	0.22	0.31	0.18	0.31	0.05	1.12

*=5% level of probability; **=1% level of probability

In case of pollen parents, SH-41, SH-72, SKI-41, Aruna, 103745 and 1379 were good general combiners for imparting earliness. Out of these, former three were good combiners for oil content, while later two were good general combiners for short plant stature.

About 33% of the total number of hybrids depicted significant *sca* effects for seed yield, of which, the hybrids SKP-8 x TMV-5 and VP-I x SKI-41 were good specific combiners for seed yield/plant in addition to high oil content and earliness. The cross, SKP-25 x 1379 had significant *sca* effect in desired direction for earliness, short plant stature and seed yield/plant. These hybrids involved both or one poor general combining parents, hence these may be directly exploited for commercial cultivation. The hybrid, SKP-82 x JI- 77 had significant *sca* effects for seed yield and also involved both good general combining parents. This hybrid may be advanced in addition to commercial exploitation for production of desirable transgressive segregants for development of improved male and female lines.

Table 3 Estimates of specific combining ability (sca) effects of selected crosses for various characters

Selected cross	Days to 50% flowering of main raceme	Days to 50% maturity of main raceme	Number of nodes up to main raceme	Plant height	Oil content	Seed yield/plant
SKP- 8 x JH-128	-1.45**	-10.19**	4.62**	0.25	-1.77**	9.97**
SKP- 8 x TMV-5	-2.73**	-5.69**	2.09	0.17	0.21*	7.95**
SKP- 25 x SH-41	-1.94**	-4.61**	-5.86**	-0.44	-0.24*	0.55
SKP- 25 x SH-72	-1.14**	-8.59**	-0.21	0.44	0.51*	18.52**
SKP- 25 x 1379	-1.59**	-3.69**	-2.79*	0.58	-0.70**	33.48**
SKP-82 x JI-77	-1.62**	-2.45**	7.94**	0.55	0.07	50.78**
SKP- 82 x 1379	-2.42**	-4.05**	-1.49	-1.70*	0.91**	2.26
VP- 1 x SKI-41	-1.99**	-6.37**	-2.14	-0.62	0.68**	29.30**
SE (gi) ±	0.44	0.63	1.11	0.37	0.05	1.12

*=5% level of probability; **=1% level of probability

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Influence of genetic and non-genetic factors on sex expression in castor, *Ricinus communis* L.

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Abstract

Information on genetic architecture of sex expression in castor which is influenced by the environmental factors provides better understanding of sex behaviour, which is helpful in maintenance of pistillate lines. The availability of 100% pistillate lines helped in commercial exploitation of hybrid vigour in castor which brought about tremendous breakthrough in productivity in the country particular in Gujarat state. Castor is highly polymorphic with respect to sex behaviour and a range of variations in sex morphology occurs within the monoecious stage flanked by complete pistillate and staminate condition at higher extremes. A critical analysis of genetic and non-genetic factors influencing sexual pollimorphism in castor has helped in identification of three types of pistillateness N, S and NES. N type pistillateness is controlled by single recessive gene in homogygous condition (ff), while, S type of pistillateness originating from sex reversal variations is governed by polygenic complex with dominance and epistatic effects. NES system besides being homozygous for sex switching gene 'f' contains environmental sensitive genes for interspersed staminate flowers (ISF) expressing under high temperature (>32°C). Use of 'N' pistillate lines (conventional) in hybrid seed programme leads to great deal of rouging less hybrid seed production and large scale rejection of hybrid seed plots due to sex instability and reversion to monoecism in any sequential order spikes. Among the three systems, 'S' system (modified) appears to be the best because of its predictable sex behaviour resulting in less rouging, more hybrid seed production/unit area and high rate of success of hybrid seed plots besides easiness in development and maintenance of such types of pistillate lines in castor.

Keywords: Pistillate line, ISF, sex expression, sibbed population, intermales, monoecious, revertant plants

Introduction

Development of castor hybrids was initiated with the introduction of an exotic pistillate line TSP 10 R and development of VP 1 indigenous pistillate line. Use of these lines facilitated the development of hybrids *viz.*, GCH-3, GAUCH-1, GCH-2, GCH-4 etc. Several new pistillate lines *viz.*, Geeta, JP-65 SKP-84 were developed by new sources and used for development and release of high yielding castor hybrids *viz.*, GCH-5, GCH-6 and GCH-7. A critical analysis of genetic and non-genetic factors influencing sexual polymorphism in castor has enabled identification of 3 systems of femaleness *viz.*, N, S, NES (Classen and Hoffman, 1950). Being a highly cross pollinated crop, large quantity of castor hybrid seeds were rejected due to improper maintenance and multiplication of the VP-1 female. At present female lines were maintained and multiplied by sibbing and selfing. The drawbacks of this method are low female ratio in population and sex reversion at early stage. The unstable sex behavior of VP-1 is due to different sources of pollen i.e., monoecious, interspersed and reverted female plants. In spite of this, well established problem of castor production are (i) low genetic purity of certified hybrid seeds (>85%), (ii) higher percentage of seeds failure (30 to 40%), and (iii) low productivity of hybrid seeds (800 kg/ha). These problems are mostly related to female parents as they are unstable for femaleness and sex behavior under field conditions. Therefore, it is worthwhile to find out ideal method for maintenance and multiplication of female which gives high female ratio with less reversals. Hence, the present studies were planned to know the sex behavior and ideal methods of maintenance of pistillate lines *viz.*, VP-1, Geeta, SKP-35, SKP-52 and SKP-93, which are mostly used in current hybridization programme for different objectives.

Materials and methods

The material for present investigation consisted of 5 pistillate lines *viz.*, VP-1 (S), Geeta (S), SKP-35 (N), SKP-52 (N) and SKP-93 (N). In each female, 3 populations *viz.*, (i) selfed population of late reverted plants, (ii) sibbed population maintained with late reversed pants and (iii) sibbed population maintained with normal monoecious plants, were used. The female parents for each line obtained from selfing of late reverted female plants and the pollinators (i) monoecious plants (1:1 ratio of male and female flowers of main spike), (ii) inter type male flowered plants (few male flowers in between female flowers in main spike) and (iii) environmentally sensitive male flowered female plants (full female up to secondary two spikes and than appearance of few male flowers) and (iv) late reverted female plants (appearance of male flowers after 6th order) were used for crossing. The former three pollen parents were selected from sibbed population of late reverted female. To obtain desired type of plants, each population was sown thrice at an interval of one month from 13.07.1995 to 16.11.95 at Main Castor Mustard Research Station, Gujarat Agricultural University, Sardarkrushinagar. In female parents, 20 plants and in pollen parents, 5 plants were tagged for observations. For maintenance of each female line, standard breeding techniques were used.

All five populations were raised under two environments i.e., under high (37.5°C on 13-07-1995) and low (32°C on 16-11-95) temperature conditions. Experiment was laid out in 3 replications with 90 cm x 60 cm distance. In each replication, 30 plants for late reverted females and 75 plants for other classes were kept for observation. All the recommended agronomic practices were followed to grow the crop successfully.

The observations were recorded on true type plants in each class and each replication. The average percentage values of observed plants were used in the subsequent analysis. The procedure for recording observations on various plants, racemes and traits for sex behaviours is described as under:

1. Number of true type plants/replication: on the basis of phenotypic characters of each female, true type pistillate plants were counted per replication.
2. Number of 100% pistillste plants/replication : plants which possessed 100% pistillate flowers on main spike were counted/replication
3. Number of monoecious plants / replication: plants which possessed monoecious sex form (male flowers on lower portion and female flowers on upper portion in 50:50% ratio) in main spike were recorded/replication.
4. Number of plants with inter type male flowers/replication: plants which possessed male flowers intermetently on main spike were recorded/replication.
5. Number of early revertant (reversion in second, third and fourth order spikes) plants/ replication: plants which produced few male flowers in second, third and fourth order spikes of each females, considered as early revertant plants were counted for replication.
6. Number of late revertant (after fourth order spike) plants/replication : plants which produced male flowers in 5th, 6th,7th, and 8th order spikes of each females, considered as late revertant plants were counted per replication.
7. Number of non revertant, (up to 8th order spikes) plants/replication : plants which had not revertant up to 8th order spikes due to high temperature or genetically in each females, considered as non- revertant plants were counted per replication.
8. Number of plants with environmentally sensitive staminate flowers (ESSF)/replication: plants which developed environmentally sensitive staminate flowers due to high temperature in 8th order spikes were counted/replication.

Results and discussion

Since last four decades, exploitation of hybrid vigour in castor on commercial scale has become feasible due to availability of 100% pistillate lines. Heterosis breeding plays significant role in increasing the productivity of castor. However, low yield of hybrid seed and lower genetic purity in seed production programme are the major problems. Increase of stable femaleness in female lines up to 4th order spikes and reduction of sex reversion in female population are needed to solve seed production problems.

By virtue of development from broad genetics base and method of reproduction through generation advancement, the female population exhibits considerable heterozygosity and heterogeneity in sex expression. The persistence of female and monoecious regions of spike through entire life span of the plant suggests the variegated nature of sex reversals. Confirming the onto-genetically irreversible nature of sex reversion form female to monoecious (Shifriss, 1956) attributed the change to a particular cell lineage. However, under field condition, it was not possible to maintain the pistillate plants beyond 15th sequential order racemes. Poor penetrance and expressivity of ISF character in the development of staminate flowers after dropping of first developed pistillate flowers was reported by Shifriss (1956). It also leads to the logical conclusion that female determining factor is dominate over male determining factor in S-type female with environmentally sensitive genes (S) for ISF. Patel *et al.* (1986), Patel *et al.* (1990) and Ramachandram and Rao (1993) suggested that the female maintained with different pollinators gave differential sex behaviour for female and male flowers and sex reversal in population. To confirm these hypothesis five castor pistillate lines (VP-1, Geeta, SKP-35, SKP-52 and SKP-93) which are widely used in selected hybrid breeding programme were tested under high temperature (first fortnight of July) and low temperature (second fortnight of November) conditions.

Female and male sex expression: The results in respect of per cent female plants in various female populations are presented in table 1. It was observed that all female lines showed similar sex behaviour pattern under each class. Hence, it is worth to describe the data of female VP-1, which a female parent of three released castor hybrids viz., GAUCH-1, GCH-2 and GCH-4. In VP-1, 100% femaleness at primary raceme level was observed in population pollinated by ESSF and late reverted selfed plant population under sowing at high and low temperature conditions. Population pollinated by intermetant male spike showed, 71.1% and 72.3% femaleness under high and low temperature, respectively. Population VP-1 x monoeciuos, showed 52.3% and 54.1% femaleness under high and low temperature, while sibbed population of VP-1 exhibited femaleness to the extent of 47% and 52.5% under high and low temperature respectively. The maximum 100% female plants were observed in VP-1 x ESSF and late reverted selfed population of VP-1, whereas, minimum femaleness 47.0 and 52.5% in sibbed population under high and low temperature.

The results of other pistillate lines *viz.*, Geeta, SKP-35, SKP-52 and SKP-93 also exhibited maximum 100% female plants at primary raceme level in the population pollinated by ESSF and late reverted selfed populations under both high and low temperature conditions. Low frequency of female plants were recorded in sibbed population of each female i.e., in Geeta (46.5% and 48.2%), SKP-35 (46.7% and 47.4%), SKP-52 (46.2% and 50.1%) and SKP-93 (46.6% and 47.8%) under both high and low temperature conditions, respectively.

From the data, it is clear that to obtain maximum frequency of pistillate plants in unit area in any of the S-type female population, it should be maintained through ESSF pollinator and by selfing of the late reverted plants. The high recovery of femaleness under these methods will also be helpful in increasing hybrid seed production. Thus, these are the best methods for obtaining higher female plant population with higher hybrid seed production along with maximum genetic purity. These findings are in conformity with results of Patel *et al.* (1986) and Ramachandram and Rao (1993).

Differential breeding behaviour of pistillate lines: The results on sex behaviour in different sequential spike orders of each female are presented in table 2. In all five pistillate lines and their various classes, none of the females showed sex reversal in primary raceme but sex reversion stage started from secondary order and was in increasing trend up to 8th raceme order under both high and low temperature planting conditions. Sex reversion was higher in high temperature planting condition than in low temperature planting condition in all classes of five females. The maximum non-reverted female plants up to 8th raceme orders (94.4% under high and 96.2% under low temperature sowing seasons) were recorded in VP-1 x ESSF population whereas, minimum in sibbed populations of SKP-52 (51% under high temperature sowing) and SKP-35 (53.3% under low temperature sowing). The range of early reversals up to 4th order was 2.3% (VP-1 x ESSF) to 25.4% (Geeta sibbed) under high temperature while, it was 1.6% (VP-1 x ESSF) to 19.2% (Geeta sibbed) under low temperature sowing conditions. Percentage of late reversals varied fro 3.3% (VP- x ESSF) to 27.3% (VP-1 sibbed) under high temperature, whereas, it was 2.2% (VP-1 x ESSF) to 26.0% (SKP-35 sibbed) under low temperature planting. The range of total reversal from low temperature sowing 3.8% (VP-1 x ESSF) to 44.7% (SKP-35 sibbed) under low temperature sowing conditions.

The results also indicated that progenies which were pollinated by monoeciuos and sib-mated in each females showed differential sex behaviour. July planting (high temperature) produced higher ISF and its proportion gradually increased in higher sequential order spikes. This trend continued up to first fortnight of November with little variation from one female to another. On the contrary, these progenies when planted in November failed to express ISF character up to 5th sequential order spikes (3rd week of March). Subsequent spikes that flowered towards end of March started throwing ISF in a very limited proportion of the population, By mid-summer, population produced large number of ISF. Distinctly marked differences in weekly maximum and minimum temperature that coincided with flowering of high and low temperature planted progenies of different females suggested the sensitivity of the sex character to prevailing temperature during flowering. For instance, the expression of ISF character was well marked in high and low temperature planted progenies, when the maximum and minimum temperatures ranged from 32° to 43°C and 15°C to 25°C, respectively. On other hand, the flowering in low temperature planted progenies which failed to produce ISF coincided with low maximum (25°C to 32°C) and minimum (9°C to 15°C) temperatures during the period December-January to end of February. Zimmerman and Smith (1966) observed marked penetrance and expressivity of ISF in CNES-1 castor pistillate line when monthly average temperature was 32.7°C in July.

Similarly, Ankineedu and Rao (1973) reported that 32 to 33°C monthly mean day temperature was desirable for maintenances of 240, a NES pistillate line. The population maintained by ESSF and late selfed plant progenies in the present studies represent the genotype combining the unconventional dominant factors for femaleness and the environmentally sensitive recessive gene (s) for ISF, the expression and penetrance of which is dependent on the genotype of the plant and favorable environment. According to variable degrees of expression of ISF character, the progenies of VP-1 female population fall into three broad categories as per experimental results. (i) produces ISF during favourable temperature irrespective of the development of pistillate flowers. These progenies remained female beyond one year thereby suggesting late/non reversion to monoecism, (ii) expresses the environmentally sensitive gene for staminate flowers under favorable environmental condition on partial or complete dropping of pistillate flowers due to non-availability of pollen. This group comprised various reverts, and (iii) does not produce staminate flowers irrespective of the season/environment and the development of pistillate flowers, late/non-reverts progenies of all three groups comes under this group. The low genetic purity in castor hybrid seed production is the main constrain for seed producers. Present studies reveal that the female population maintained by ESSF pollinators and selfing of late reverted plants showed minimum reversion from second to 8th order spikes. The less availability of pollen grains from the revertant spikes in the population, thereby less chances of selfing in hybrid seed production. Thus, this true type population will be helpful in increasing genetic purity of hybrid seeds.

From the data, it was also evident that there was high reversion (male induction) in female plants population under high temperature (beyond 32°C) as compared to low temperature (below 30°C). Hence, raising the hybrid seed production plots under low temperature conditions (below 32°C at flowering time) and maintenance of female lines under high temperature will be advantageous for recovery of higher seed yield with high genetic purity. It was also clear that the reversion (male induction) in female population upto 4th order (32°C) is under limit. Therefore, it is advocated that for maintenance of high genetics purity of hybrid seeds, spikes upto 4th order should be harvested.

Efficient method of maintenance of pistillate lines: The results on maintenance of different pistillate lines through various pollinators (Table 1 and 2) indicated that the maximum (100%) female plants and non/late reverted female plants (up to 8th order spikes) were recorded in female populations which were maintained through ESSF followed by selfing of late reverted higher order spikes plants and inter mating under both high and low temperature conditions in all the five females. The same trend was also observed in early reverted group in all the females under both sowing conditions. The maximum 94.4% and 96.2% non-reverted female plants were observed under high and low temperature respectively maintained by VP-1 x ESSF. The minimum non revertant female plants 51.0% in SKP-52 sibbed and 55.3% in SKP-35 sibbed population were observed under high and low temperature sowing, respectively.

The sex expression in differential breeding behaviour of the progenies with particular reference to penetrance and expressivity of environmentally sensitive gene(s) for ISF indicated the feasibility of manoeuvring the progenies that ensure 100% recovery of female plants as against 45 to 55% in current method. Essentially the alternate method of reproduction should be based on the use of true breeding late/non-reverted female line which carries environmentally sensitive gene(s) for ISF. Its self reproduction is accomplished in male promoting environment (summer).

It is a normal practice to keep 15 to 20% monoecists as a source of pollen for seed multiplication of VP-1 conventional female which, results in 50 to 60% monoecious plants in female lines of hybrid seed production. These monoecists are to be rouged out before anthesis in hybrid seed production plots, which result into low hybrid seed production/unit area. Unremoved monoecists and early revertants deteriorate genetic purity of hybrid seed and lead to rejection of hybrid seed plots.

Patel *et al.* (1990) recommended that the maintenance and multiplication of VP-1 (modified) female can be done by selfing and sibing. For achieving the goal, either early (June-July) or late (January-February) planting would be helpful. This is because in both the plantings, flowering coincides with higher temperature (above 32°C). It is worth while to note that the maintenance of this line and hybrid seed production could, therefore, be accomplished at the same location by adjusting the planting time. It is also possible to maintain the line by using the female plants of the hybrid seed production programme. The female VP-1 modified has, therefore, advantages for (i) maximum genetic purity in femaleness, maintenance by selfing and sibbing and maintance and establishing crossing block at the same location. Thus, saving inputs and time for separate plantings. (ii) seed rate of female line could be reduced from 7.5 kg/ha to 3 to 4 kg/ha as a result of higher recovery of female plants and reduction in the cost of rouging in seed production programme, (iii) complete absence of monoecists in female lines ensuring higher genetic purity of hybrid seed, minimizes the rejection of seed plots.

Table 1 Sex behaviour of different pistillate lines of castor maintained by different pollinators and raised under high and low temperature conditions

Populations	% female and monoecious plants			
	High temperature		Low temperature	
	Female	Monoecious	Female	Monoecious
VP-1 x Monoecious	52.3	47.7	54.1	45.9
VP-1 x Inter males	71.1	28.9	72.3	27.7
VP-1 x E.S.S.F	100.0	00.0	100.0	00.0
VP-1 x (LR) Selfed	100.0	00.0	100.0	00.0
VP-1 x (N) Sibbed	47.0	53.0	52.5	47.5
Geeta x Monoecious	51.3	48.7	52.9	47.1
Geeta x Inter males	70.7	29.3	74.5	25.5
Geeta x E.S.S.F	100.0	00.0	100.0	00.0
Geeta (LR) Selfed	100.0	00.0	100.0	00.0
Geeta (N) Sibbed	46.5	53.5	48.2	51.8
SKP-35 x Monoecious	47.8	52.2	49.3	50.7
SKP-35 x Inter males	66.7	33.3	69.5	30.5
SKP-35 x E.S.S.F	100.0	00.0	100.0	00.0
SKP-35 (LR) Selfed	100.0	00.0	100.0	00.0
SKP-35 (N) Sibbed	46.7	53.3	47.4	32.6
SKP-52 x Monoecious	45.9	54.1	49.2	49.8
SKP-52 x Inter males	64.7	35.5	66.5	33.5
SKP-52 x E.S.S.F	100.0	00.0	100.0	00.0
SKP-52 (LR) Selfed	100.0	00.0	100.0	00.0
SKP-52 (N) Sibbed	46.2	53.8	50.1	49.9
SKP-93 x Monoecious	44.9	55.1	50.0	50.0
SKP-93 x Inter males	59.1	40.9	66.7	33.3
SKP-93 x E.S.S.F	100.0	00.0	100.0	00.0
SKP-93 (LR) Selfed	100.0	00.0	100.0	00.0
SKP-93 (N) Sibbed	*46.6*	*53.4*	*47.8*	*52.2*

LR= Late reverted plants; N= Normal type; ESSF= Environmental Sensitive Staminate Flowers

Table 2 Spike-orderwise per cent female revertant plants in different pistillate lines under high and low temperature conditions

Progeny back ground	% early revertant female plants up to 4th order spikes								% late revertant female plants after 4th order spikes								% non-revertant female plants up to 4th order spikes		% revertant plants	
	Primary spike		S1/S2		T1/T2		Total		Q1/Q2		P1/P2		H1/H2		Total					
	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
VP-1 x Monoecious	00.0	00.0	5.2	2.0	7.7	2.3	12.9	4.3	5.6	2.1	6.8	2.2	6.1	3.2	18.5	7.5	68.6	88.2	31.4	11.8
VP-1 x Inter males	00.0	00.0	4.8	2.9	7.5	5.3	12.3	8.2	4.2	2.4	5.4	2.8	5.6	4.2	15.2	9.4	72.5	82.4	27.5	17.6
VP-1 x E.S.S.F	00.0	00.0	1.2	00.0	1.1	1.6	2.3	1.6	00.0	00.0	1.2	00.0	2.1	2.2	3.3	2.2	94.4	96.2	4.5	3.8
VP-1 x (LR) Selfed	00.0	00.0	3.6	00.0	4.8	3.8	8.4	3.8	2.7	00.0	3.9	2.3	4.8	2.4	11.4	4.4	80.2	91.5	19.8	8.5
VP-1 x (N) sibbed	00.0	00.0	8.4	4.2	9.6	9.2	18.0	13.4	8.2	8.7	9.5	9.3	9.6	7.8	27.3	25.8	54.7	60.8	45.3	39.2
Geeta x Monoecious	00.0	00.0	5.8	2.3	8.0	2.8	13.8	5.8	6.1	2.0	6.7	2.2	7.2	2.2	20.0	6.4	66.2	88.5	33.8	11.5
Geeta x Inter males	00.0	00.0	4.7	3.0	6.4	4.8	11.1	7.8	4.4	2.2	5.2	3.2	5.6	5.1	15.2	10.6	73.7	81.6	26.3	18.4
Geeta x E.S.S.F	00.0	00.0	1.4	00.0	1.2	1.8	2.6	1.8	00.0	00.0	2.1	1.00	2.5	1.9	4.6	2.9	92.8	95.3	7.2	4.7
Geeta (LR) Selfed	00.0	00.0	4.1	1.0	5.1	2.1	9.2	3.1	3.8	00.0	4.4	3.2	4.8	3.5	12.3	6.7	78.5	90.2	21.5	9.8
Geeta (N) sibbed	00.0	00.0	12.2	7.2	13.2	12.0	25.4	19.2	5.9	6.8	7.0	7.6	8.9	7.8	21.8	22.2	52.8	58.6	47.2	41.4
SKP-35 x Monoecious	00.0	00.0	6.6	3.1	9.1	4.5	15.7	7.6	5.6	2.9	6.2	3.4	6.7	3.6	18.5	9.9	65.8	82.5	34.2	17.5
SKP-35 x Inter males	00.0	00.0	4.8	2.3	7.6	4.0	12.4	6.3	4.7	4.1	5.9	4.7	6.7	4.8	17.3	13.6	70.3	80.1	29.7	19.9
SKP-35 x E.S.S.F	00.0	00.0	2.1	1.2	2.9	2.3	5.0	3.5	00.0	00.0	3.0	2.1	3.3	2.8	6.3	4.9	88.7	91.6	11.3	8.4
SKP-35 (LR) Selfed	00.0	00.0	4.3	1.8	6.2	2.4	10.5	4.2	4.1	1.8	4.8	2.3	5.1	2.5	14.0	6.6	75.7	89.2	24.5	10.8
SKP-35 (N) sibbed	00.0	00.0	10.4	7.9	11.4	10.8	21.8	18.7	7.9	7.5	9.2	8.8	9.7	9.7	26.8	26.0	51.4	55.3	48.6	44.4
SKP-52 x Monoecious	00.0	00.0	8.2	2.4	9.0	4.4	17.2	6.8	5.3	1.9	6.4	2.5	7.0	3.5	18.7	7.9	64.1	85.3	35.9	14.4
SKP-52 x Inter males	00.0	00.0	5.3	00.0	9.1	5.9	14.4	5.9	4.8	3.6	5.4	4.0	6.7	4.1	16.9	11.7	68.7	82.4	31.3	17.6
SKP-52 x E.S.S.F	00.0	00.0	2.2	00.0	3.1	2.1	5.3	2.1	00.0	00.0	3.0	00.0	3.2	2.7	6.2	2.7	88.5	95.2	11.5	4.8
SKP-52 (LR) Selfed	00.0	00.0	4.2	00.0	6.6	3.7	10.8	3.7	1.5	00.0	4.8	2.2	5.2	3.0	11.5	5.2	77.7	91.1	22.3	8.9
SKP-52 (N)*sibbed	00.0	00.0	11.1	8.8	12.1	10.2	23.2	19.0	7.9	6.4	8.7	6.5	9.2	7.1	25.8	20.0	51.0	61.0	49.0	39.0
SKP-93 x Monoecious	00.0	00.0	6.2	3.5	7.4	4.0	13.6	7.5	5.2	2.3	6.0	2.9	8.2	3.1	19.4	8.3	67.0	84.2	33.0	15.8
SKP-93 x Inter males	00.0	00.0	5.2	2.3	5.9	4.0	11.1	6.3	4.5	2.0	5.2	2.8	6.5	3.2	16.2	8.0	72.7	85.1	27.3	14.3
SKP-93 x E.S.S.F	00.0	00.0	2.0	00.0	2.2	2.8	4.2	2.8	00.0	00.0	3.0	1.9	3.5	2.3	6.5	4.2	89.3	93.0	10.7	7.0
SKP-93 (LR) Selfed	00.0	00.0	4.1	1.3	5.6	2.4	9.7	3.7	3.7	1.7	3.8	2.0	4.3	2.0	11.8	5.7	78.5	90.6	21.5	9.4
SKP-93 (N) sibbed	00.0	00.0	11.3	7.8	12.1	10.3	23.4	18.5	7.2	7.4	8.5	8.6	8.9	8.8	24.6	24.8	52.0	56.7	48.0	43.3

ESSF= Environmental Sensitive Staminate Flowers; LR= Late reverted plants; H= High temperature sowing (13.7.95); N= Normal type; L= Low temperature sowing (16.11.95)

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Effect of planting ratio on seed yield of hybrid castor, DCH-177

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Abstract

A field experiment was conducted at seed unit, UAS, Raichur during *rabi* 2008-09 to know the effect of planting ratio on hybrid seed yield of castor hybrid DCH-177. Five different planting ratio's (2:1, 3:1, 4:1, 5:1 and 6:1 female to male ratios) were dibbled with 4 replications. The yield parameter like number of capsules/plant, seed yield/plant (g) and seed yield (kg/ha) were recorded. The study envisaged that, hybrid seed yield of DCH-177 was significantly influenced by increasing planting ratio (female to male). Increase in seed yield was noticed from 598.8 kg/ha with existing 3:1 planting ratio to 633.7 kg/ha with 4:1 planting ratio. However further increase in planting ratio decreased the seed yield. Hence planting ratio of 4:1 is better for seed production of DCH-177.

Keywords: Castor, planting ratio, seed yield

Introduction

Castor occupies an important place in the dryland agriculture owing to its drought hardiness, quick growth, ability to adjust to edaphic, climatic, and managerial factors and low input requirements. Oil from castor is among the most versatile products with varied industrial uses. The castor hybrid, DCH-177 was developed by involving DPC- 9 as female parent and DSP- 9 as male parent. The planting ratio of male and female parental lines and row-to-row spacing have a direct impact on the quantity of hybrid seed produced. In order to enhance hybrid seed yield, availability of pollen is must. Present investigation on effect of planting ratio on seed yield of DCH-177 was undertaken to know the influence of different planting ratios on hybrid seed yield.

Materials and methods

Parental lines of DCH-177 were grown in randomized black design with four replications during *rabi* season of 2008-09. Seeds of female parent (DCP-9) and male parent (DCS-9) *were dibbled in* 2:1, 3:1, 4:1, 5:1 *and* 6:1 *with the spacing of* 90 cm x 60 cm. Two rows of sorghum were grown two weeks prior to sowing of parental lines to minimize cross pollination between treatments. Recommended package of practices were followed to raise a healthy crop. The yield parameters like number of capsules/plant, seed yield/plant (g) and seed yield (kg/ha) were recorded (Table 1).

Table 1 Effect of planting ratio on hybrid seed yield of castor, DCH-177

Planting ratio	Plant height (cm)	No. of primary branches	No. of capsules/plant	100 seed weight (g)	Seed yield/plant (g)	Seed yield (kg/ha)
2:1	133.6	3.0	98.7	29.5	43.3	534
3:1	132.7	3.0	99.2	29.9	43.1	599
4:1	133.4	3.8	99.7	30.5	42.2	634
5:1	134.8	3.5	95.0	30.0	39.0	602
6:1	133.4	3.4	94.2	29.6	37.7	593
Mean	133.9	3.3	97.4	30.1	41.1	33
CD (P=0.05)	NS	NS	3.45	0.84	2.33	

and JP-102 x JI 376 were found good specific combiners for effective length of primary raceme. Negative values of *sca* were considered desirable for days to 50% flowering of primary raceme, height up to primary raceme and number of nodes up to primary raceme. The magnitude of *sca* effect revealed that the cross combinations, JP-102 x JI-368, JP-101 x SKI-215, JP-96 x SKI-215 and JP-102 x JI-377 for days to 50% flowering of primary raceme, JP-102 x SKI-215, JP-96 x JI-368, JP-101 x JI-376 and JP-101 x SKI-291 for number of nodes up to primary raceme and JP-102 x JI-368, JP-101 x SKI-215, JP-96 x SKI-215 and JP-102 x JI-377 for days to 50% flowering of primary raceme exhibited significant and negative values of *sca* effect. Total 9 cross combinations gave significant and positive *sca* effect for number of nodes on primary raceme. The best specific cross combination was JP-96 x SKI-215 followed by JP-96 x JI-377, JP-102 x JI-368 and JP-102 x JI-396.

The reflections on parents viz., JP-102 and JP-96 (females) and JI-376 and SKI-215 (males) from the combining ability analysis would suggest that base population build up from these parents would certainly be ideal for carrying selection for higher gca and high sca. A combination of poor combiners also gives several crosses with high and significant sca effects across the traits, such crosses could be expected to throw up some transgressive segregants in recurrent selection. A progeny selection with pedigree method in such crosses may throw up transgressive segregants leading to development of good inbreds.

Table 3 Specific combining ability effects in castor

Crosses	Plant height upto primary raceme	Effective length of primary raceme	No. of nodes upto primary raceme	No. of capsules on primary raceme	Days to 50% flowering	No. of effective racemes/plant	100 seed weight	Oil content	Seed yield/plant
JP-96 x JI-368	-8.13**	-1.57	-0.04	-10.35**	1.65*	-0.85	1.02	-0.30	32.57*
JP-96 x JI-372	-5.13**	-4.02**	-0.37	-7.13**	0.20	-1.30	0.34	-0.14	-26.43
JP-96 x JI-376	1.20	0.54	-1.15*	-7.46**	-1.24	1.04	0.23	0.29	-15.43
JP-96 x JI-377	3.54**	0.76	-1.15*	7.20**	0.87	-0.41	1.33*	0.28	11.91
JP-96 x SKI-215	9.54**	4.54**	2.52**	19.32**	-3.24**	0.82	-0.39	0.41	20.13
JP-96 x SKI-291	-1.02	-0.24	0.19	-1.58	1.76*	0.70	-2.52**	-0.54	-22.76
JP-101 x JI-368	1.76	1.82	-0.32	3.43*	2.20**	-0.46	0.04	-0.48	-22.43
JP-101 x JI-372	-1.91*	0.04	0.69	3.65**	1.09	-0.91	0.99	-0.35	-45.76**
JP-101 x JI-376	-5.57**	-2.41*	1.24*	2.98*	-0.35	-0.91	0.71	-0.63*	17.91
JP-101 x JI-377	-0.91	2.48**	-0.09	-5.69**	1.76*	-0.35	-0.38	0.01	19.91
JP-101 x SKI-215	2.09*	-1.74	-0.43	-7.57**	-3.69**	1.54	-1.68**	0.63*	9.80
JP-101 x SKI-291	4.54**	-0.19	-1.09*	3.20*	-1.02	1.09	0.33	0.83**	20.57
JP-102 x JI-368	6.37**	-0.24	0.35	6.93**	-3.85**	1.32	-1.06	0.78**	-10.15
JP-102 x JI-372	7.04**	3.98**	-0.32	3.48*	-1.30	2.20*	-1.33*	0.49	72.19**
JP-102 x JI-376	4.37**	1.87*	-0.09	4.48**	1.59*	-0.13	-0.94	0.34	-2.48
JP-102 x JI-377	-2.63**	-3.24**	1.24*	-1.52	-2.63**	0.76	-0.94	-0.28	-31.82*
JP-102 x SKI-215	-11.63**	-2.80**	-2.09**	-11.74**	6.93**	-2.35*	2.07**	-1.04**	-29.93*
JP-102 x SKI-291	-3.52**	0.43	0.91	-1.63	-0.74	-1.80	2.20**	-0.28	2.19
S E (Sij)	0.96	0.95	0.51	1.38	0.74	0.97	0.63	0.29	14.91

* and ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively.

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Genotype x environment interaction and stability parameters for yield and component characters in castor, *Ricinus communis* L.

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Abstract

The stability parameters were studied with 16 parents (4 pistillate and 12 monoecious lines) and their 48 hybrids using three created environments during crop season of the year 2007-08. Mean square due to genotypes and environments (linear) were significant for all the characters under study. The values of mean square due to genotypes x environments interaction were significant for plant height up to primary spike, shelling outturn and oil content. Accordingly, linear component of G x E interaction was significant for above stated characters, and it was of greater magnitude than G x E (non-linear) component, which suggested that performance of genotypes would be predictable in different environments. None of the crosses was stable for all the characters in the same environment; therefore, the same cross had well adaption to different environments for different characters. The cross, VP 1 x DCS 47 was well adapted to poor environment for plant height and to better environment for number of tertiary spikes/plant as well as shelling outturn. However, for seed yield/plant, stability parameters were not computed as genotypes x environments interaction had non-significant value of mean square; therefore, estimates of stability parameters for other characters had less importance.

Keywords: Genotype, environment, monoecious line, pistillate line, castor

Introduction

The interplay of genes and environment is of vital significance in the expression of a character. Castor crop is more sensitive to environmental variations, particularly differences for fertility status of soil, temperature during growth period and moisture availability. The sensitivity of castor genotypes/ hybrids to environmental variations suggests the need of using array of environments instead of single environment to study the nature of gene effect controlling the inheritance of components of adaptation. In view of this, four pistillate lines, 12 inbreds and their 48 F_1 crosses were evaluated to study response of genotypes for seed yield and other matricate characters over three varying environments created through dates of sowing and irrigation schedules.

Materials and methods

Diverse four pistillate lines and 12 monoecious inbreds (inter spersed male flowers) were crossed in Line x Tester mating design. Seeds of parents and 48 F_1s were sown on: (i) August 1, 2007 under rainfed cropping condition; (2) September 4, 2007 with irrigation only at critical growth stages i.e., flowering initiation and seed development stage and (iii) October 5, 2007 under irrigation condition; as and when required.

The investigation was carried out at Regional Research Station, Anand Agricultural University, Anand during the year 2007-08. The experiment for each environment was laid out in a randomized complete block design with three replications, keeping a single row of 7.2 m for each entry with 120 cm and 60 cm inter and intra row spacing, respectively. Total 14 characters comprising five growth attributes, seven yield component characters, seed yield and oil content were studied. The statistical analysis was done as per Eberhart and Russell (1966). However, Bartlett's test of homogeneity of variance was applied to the error mean squares.

Results and discussion

The Bartlett's test suggested that created environments significantly differed in case of all the characters under study. The analysis of variance over environments revealed that the mean squares due to genotypes were highly significant for all the characters. Highly significant estimates of mean square due to environments (linear) indicated existence of considerable variation among the created environments for all the characters except test weight of 100 seeds. The values of mean square due to genotypes x environment interaction were significant for plant height up to primary spike, shelling outturn and oil content, which revealed that genotypes behaved differently with array of environments for these characters.

The values of mean square due to E + (G x E) were significant for plant height up to primary spike, number of secondary spikes/plant, number of tertiary spikes/plant, shelling out turn and oil content suggesting variable response of genotypes to different environments. Further, significance of G x E (linear) component for plant height up to primary spike, number of tertiary spikes/plant, shelling outturn and oil content indicated that all the regression coefficients were not statically at par and variation in the performance of genotypes was due to regression of genotypes on environmental indices. Pooled deviation variance G x E (non-linear) was significant for all the characters except shelling outturn and oil content. However, observed G x E (non-linear) effect was of lower magnitude than its counter part G x E (linear), which indicated that the characters registered G x E interaction had inconsistent performance over environments.

The observed high magnitude of genotypes x environment (linear) component could lead to the identification of genotypes deviating from the regression line of unit slope. Accordingly, three kinds of linear response; bi=1, bi>1 and bi <1 have been observed for the characters under consideration, However, negative bi values were also observed, *such type of linear response could be attributed* to inadequacy of the scale used for analysis, and/or the inherent behaviour of the genotypes investigated. (Knight, 1970).

For the character plant height up to primary spike, population mean was 73.44 cm, hence, genotypes having less plant height than population mean, non significant values of S2di and significant deviation from unit slope of regression coefficient (bi) were considered as stable genotype. Total 12 genotypes were identified as well adapted to various environmental conditions; of which pistillate line VP 1 and SKP 84, male parents PCS 124, and SKI 192, hybrids Geeta x SKI 147, VP 1 x DCS 47, VP 1 x EB 16, VP 1 x EC 38538, VP 1 x SKI 192 and VP 1 x SKI 270 had above average stability and adapted to poor environment as their bi *values were below one. The pistillate line SKP 24 and hybrid SKP 24 X SKI 202 had larger* bi values than unity, thereby these had below average stability and well adaptability to better environment.

For the character number of tertiary spikes/plant, population mean was 3.44; therefore, genotypes having higher number of tertiary spikes than 3.44, and fulfilling other stability parameters were identified as well adapted to different environments. Inbreds, EC 38538 and hybrids VP 1 x DCS 47 and SKP 84 x EB 16 were well adapted to better environment, none of the genotypes was well adapted to poor environment: Whereas, inbred EB16 and hybrid VP 1 x GC 2 were wide adapted genotypes as both the genotypes had close to one estimate of regression coefficient. The population mean was 64.95% for shelling outturn. Total 25 genotypes showed better adaptation to different environments. However, none of the genotype was well adapted to poor environment. Inbred EB16, and hybrids, Geeta x EB16, Geeta x SH 41, Geeta x SKI 147; Geeta x SPS 44-1, VP 1 x EC 38538 and SKP 84 x DCS 47 had below average stability and well adapted to favourable environment. Among the genotypes, which showed average stability, hybrid Geeta x PCS124 exhibited the highest shelling outturn followed by SKP 24 x SPS 41-1, VP 1 x SKI 270 and SKP 84 x EC 38538. Only one inbred, SKI 202 was wide adapted to different environments.

Table 1 Analysis of variance for phenotypic stability for different characters in castor

Characters	*Mean sum of squares*							
	Genotypes (g)	Environments (e)	g x e	e + (g x e)	Environments (linear)	g x e (linear)	Pooled deviation	Pooled error
d. f.	65	2	130	132	1	65	66	390
Days to 50 % flowering	94.08 **	70.82 **	10.16	11.08	141.65 **	11.52	8.66 **	0.54
Days to 50 % maturity of primary spike	755.62 **	106.00 **	16.92	18.27	211.99 **	14.03	19.52 **	2.70
Plant height up to primary spike	980.34 **	5884.96 **	387.08 *	470.38 **	11769.91 **	531.12 **	239.37 **	14.05
Number of nodes up to primary spike	19.45 **	23.93 **	0.47	0.83 **	47.86 **	0.45	0.49 **	0.21
Effective length of primary spike	363.58 **	730.59 **	65.27	75.35	1461.19 **	63.15	66.37 **	13.45
Number of secondary spikes/plant	5.02 **	58.00 **	2.21	3.06 *	116.00 **	2.37	2.03 **	0.05
Number of tertiary spikes/plant	4.36 **	31.83 **	1.56	2.02 **	63.66 **	1.98 *	1.12 **	0.05
Number of effective branches/plant	20.28 **	81.82 **	5.58	6.74	163.63 **	6.38	4.72 **	0.37
Number of capsules on primary spike	940.98 **	3120.92 **	298.89	341.65	6241.83 **	326.67	267.00 **	24.82
Total number of capsules/plant	8329.08 **	32902.32 **	2427.30	2889.04	65804.64 **	2372.25	2444.73 **	182.97
Seed yield/plant	7158.10 **	18857.49 **	1590.66	1852.28	37714.97 **	1626.29	1531.47 **	142.02
Shelling outturn	100.04 **	993.12 **	0.17 **	15.21 **	1986.24 **	0.27 **	0.07	2.68
100 seed weight	37.57 **	0.65	2.52	2.49	1.29	2.29	2.70 **	0.19
Oil content	13.47 **	6.37 **	0.02 **	0.11 **	12.74 **	0.03 **	0.00	0.19

*, ** Significant at 5 and 1% level of significance, respectively

For oil content, population *mean* was 49.36%. Total 24 genotypes were well adapted to various environments; among those, four hybrids, Geeta x DCS 9 (49.83%), Geeta x DCS 47 (49.64%), VP 1 x EB 16 (49.86%) and SKP 84 x SPS 44-1 (50.40%) had above average stability, hence, these were well adapted to poor environment. Among the eight well adapted genotypes to better environment, hybrid VP 1 x SKI 270 had the highest oil content followed by inbred SKP 24 and hybrid SKP 84 x EC 38538; whereas, among 12 wide adapted genotypes to different environments, inbred EC 38538 had the highest oil content and other promising genotypes were VP 1 x EC 38538, PCS 124, Geeta x SKI 192, Geeta x EB 16, VP 1 x SKI 202 and VP 1 x DCS 9. Significance of G x E (L) component for plant height up to primary spike, number of tertiary spike/plant, shelling outturn and oil content was in accordance with the reports of Henry and Daulay (1985), Solanki and Joshi (2003) and Patel and Pathak (2006).

None of the hybrids was found consistently stable for all the characters in any environment. For seed yield/plant and important yield component characters *viz.*, number of capsules/plant, number of capsules on primary spike, number of effective branches/plant, test weight of 100 seed, effective length of primary spike and number of secondary spikes/plant G x E interaction and its linear component G x E (L) were non- significant, which suggested non existence of linear response of genotypes to varied environments, and significance of G x E (non-linear) component revealed that performance of genotypes could not be predicated over environments for above stated characters.

Table 2 **Classification of genotypes based on their adaptation in average, better and poor environment for different traits in castor**

Environments	Plant height up to primary spike	Number of tertiary spikes/plant	Shelling outturn	Oil content
Average stability and wide/ general adaptability		VP 1 x GC 2	Geeta x GC 2 Geeta x PCS 124 Geeta x SKI 202 VP 1 x DCS 47 VP 1 x EB 16 VP 1 x SH 41 VP 1 x SKI 270 SKP 24 x GC 2 SKP 24 x SKI 202 SKP 24 x SPS 44-1 SKP 84 x EB 16 SKP 84 x EC 38538 SKP 84 x SPS 44-1	Geeta x EB 16 Geeta x SKI 147 Geeta x SKI 192 Geeta x SKI 270 Geeta x SPS 44-1 VP 1 x DCS 9 VP 1 x EC 38538 VP 1 x GC 2 VP 1 x SKI 202
Below average stability and adapted to better environment	**SKP 24 x SKI 202**	**VP 1 x DCS 47** **SKP 84 x EB 16**	Geeta x EB 16 Geeta x SH 41 Geeta x SKI 147 Geeta x SPS 44-1 VP 1 x EC 38538 SKP 84 x DCS 47	VP 1 x SKI 270 SKP 84 x DCS 47 SKP 84 x EB 16 SKP 84 x EC 38538
Above average stability and adapted to poor environment	Geeta x SKI 147 VP 1 x DCS 47 VP 1 x EB 16 VP 1 x EC 38538 VP 1 x SKI 192 VP 1 x SKI 270			Geeta x DCS 9 Geeta x DCS 47 VP 1 x EB 16 SKP 84 x SPS 44-1

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Sex expression studies in pistillate lines of castor, *Ricinus communis* L.

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Abstract

In the present investigation, 20 pistillate lines were planted at two dates of sowings to understand the influence of date of sowing on pistillate expression. Recovery of pistillate and moniecious plants was not influenced by date of sowing while number of interspersed staminate flower was influenced.

Keywords: Castor, combining ability

Introduction

Sex expression in castor (*Ricinus communis* L.) is influenced by both genotype and environment, where in a better management improves the proportion of femaleness and stress conditions increase the proportion of maleness. The development of pistillate lines in castor has played the key role in commercial exploitation of hybrids in castor in Gujarat state bringing in quantum jump in productivity. For seed production of hybrids in commercial scale, a stable pistillate line is a prerequisite.

Materials and methods

In the present investigation, 20 promising pistillate lines developed at the station were planted at two dates of sowing (August 2 and August 23) in randomized block design with two replications at Main Castor-Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar during rainy season of 2004 and evaluated for sex expression traits *viz.*, recovery of pistillate and monoecious plants and number of interspersed staminate flowers (ISF) in different orders of spikes *viz.*, P_1, S_1, S_2, S_3, S_1T_1, S_1T_2, S_2T_1 and S_2T_2.

Results and discussion

Analysis of variance (Table 1) revealed significant difference among genotype for all the traits. The date of sowing did not influence the recovery of pistillate and monoecious plants, which revealed that these traits are not influence by environment and are strictly under the genotype control. Interaction effect of genotype x date of sowing was also found to be non-significant for recovery of monoecious and pistillate plants. Which revealed that the behaviour of all the pistillate lines were consistent over environment. However date of sowing and interaction effect significantly influenced the number of ISF in primary and sub-sequent orders. Which revealed that the number of ISF are highly influenced by environment in different orders of the spikes among the genotype. The magnitude of σ^2g and GCV were found less than σ^2p and PCV, respectively (Table 2) which also revealed that recovery of ISF in various order of the spikes are highly influenced by environmental factors. High estimate of heritability (>50%) for number of ISF in different orders of spikes suggested that the selection will help in be effective in reducing the number of ISF in different orders of the spikes in these pistillate lines of the castor. The pistillate lines SKP 23, SKP 84, SKP 116, JP 65, VP 1 JP 93 and Geeta giving high recovery of pistillate plants along with less number of ISF in different orders of the spikes appears to be highly stable pistillate line and can be extensively used in hybrid breeding programme. These results are inconsonance with the finding of Shifriss (1960), Zimmerman and Smith (1966) and Ankineedu and Rao (1973).

Table 1 Analysis of variance pooled over environments for different sex characters in castor, *Ricinus communis* L.

Source of Variation	d.f.	Mean sum of square									
		% monoecious plant	% pistillate plant	Number of ISF in different order spikes							
				P_1	S_1	S_2	S_3	S_1T_1	S_1T_2	S_2T_1	S_2T_2
Replication	1	0.00	0.00	0.82	1.51**	0.78**	0.27	0.05	0.00	0.00	0.02
Sowing date (E)	1	0.00	0.00	83.09**	0.05	0.08	0.11	0.11	0.17	0.32	0.84
Varieties (G)	19	451**	4.53**	13.13**	2.73**	2.39**	2.18**	1.39**	0.94**	1.36**	2.27**
Sowing date x Varieties	19	0.00	0.00	7.68**	0.09	0.06	0.07	0.19**	0.07	0.14*	0.18
Error	39	0.23	0.235	2.82	0.20	0.11	0.08	0.08	0.05	0.07	0.21
Total	79	1.20	1.21	7.46	0.80	0.65	0.58	0.42	0.27	0.40	0.71

*,** significant at 5% and 1% level of significance, respectively

Table 2 Variability parameters, heritability and genetic advance for different sex characters for the data pooled over environment in castor

Parameters	% monoecious plants	% pistillate plants	Number of ISF in different order spikes							
			P_1	S_1	S_2	S_3	S_1T_1	S_1T2	S_2T_1	S_2T_2
P	0.534	0.537	4.26	0.38	0.32	0.33	0.23	0.11	0.23	0.39
G	0.317	0.318	3.23	0.25	0.21	0.24	0.16	0.05	0.17	0.28
E	0.218	0.219	1.03	0.13	0.11	0.09	0.07	0.05	0.06	0.11
PCV (%)	307.8	0.735	119.2	136.2	148.5	16.30	171.3	179.5	192.5	241.8
GCV (%)	237.0	0.567	103.8	110.8	120.0	136.6	142.2	125.9	164.8	205.8
Heritability (%)	59.30	59.20	75.81	66.19	65.18	72.60	68.93	49.20	73.34	72.40
Genetic advance (%) Mean	0.893	0.894	3.22	0.84	0.75	0.86	0.68	0.33	0.72	0.93

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Study of combining ability for yield and its components in castor, *Ricinus communis* L. through line x tester analysis

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Abstract

Line x tester analysis using four females and 10 males was carried out to estimate combining ability and nature of gene action in castor (*Ricinus communis* L.) for 10 different characters during rainy season of 2004. The analysis of variance for combining ability and the estimates of variance ratio ($\sigma^2 gca/\sigma^2 sca$) revealed that the non-additive gene action was predominantly involved in expression of all the traits. The hybrids SKP 106 x PCS 124, SKP 106 x SKI 294, Geeta x SKI 192, SKP 106 x SKI 299 and SKP 106 x SH 41 exhibited higher specific combining ability effects in desired direction for seed yield/plant and its attributes. The estimates of *gca* effects indicated that the female parent, SKP 106 was good combiner for seed yield and also other important traits. Whereas, Geeta was a good combiner for seed yield, number of effective spikes and oil content.

Keywords: Combining ability, yield components, castor

Introduction

Hybrid castor (*Ricinus communis* L.) was a great success in India. Pistillate liner paved way to exploit heterosis especially for seed yield. In order to obtain high combining aparental combinations, understanding of general and specific combining ability of parental lines is essential. Therefore, the present study was undertaken to identify high combining parents and their cross combinations.

Materials and methods

Four pistillate lines (VP 1,Geeta, SKP 42 and SKP 106 and 10 pollinator parents *viz.*, SKI 192, SKI 215, SKI 232, SKI 294, SKI 299, SH 41, 1-21, JI 273, EC-38538 and PCS 124 having sufficient variability for seed yield and other component characters, were crossed in a line x tester mating design. Forty hybrids and one standard check, GCH 4, along with 14 parents (4 lines and 10 testers) were evaluated at Main Castor-Mustard Research Station , Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during rainy season of 2004. The spacing between row to row was 90 cm and plant to plant within a row was 60 cm. Recommended package of practices (for irrigation condition) were adopted to grow the crop. Each genotype was grown in a single row of 10 plants. Observation were recorded on five randomly selected plants for 10 characters *viz.*, days to 50% flowering, days to maturity, number of nodes upto primary raceme, plant height, effective length of main raceme, number of capsule on main raceme, number of effective branches/plant, 100 seed weight, oil content and total seed yield/plant.

Results and discussion

The analysis of variance (Table 1) for combining ability exhibited that the mean square due to females were significant for most of the characters except days to 50% flowering and number of capsule on primary spike. Whereas, mean square due to males were significant for plant height, number of node up to primary spike, length of main spike and oil content. Further, the variance due to lines was higher than that of male for all the characters. The mean square due to line x tester interaction was significant for all the characters except number of effective spikes/plant and seed yield, which indicates that experimental material possessed considerable variability and that gca and sca were involve in the genetic control of various traits. The *gca/sca* ratio ($\sigma^2 gca/\sigma^2 sca$) was less than one for all the characters. This indicates that the non-additive components of genetic variance was predominantly involved in the expression of yield and its attributing characters. Similar results were reported by Patel (2005) for seed yield/plant, number of capsules on main raceme and length of main raceme, Joshi *et al.* (2001) for days to flowering, Solanki and Joshi (2000) reported non-additive gene action for days to maturity. Golakia *et al.* (2004) reported non-additive gene action for number of nodes and plant height and Kanwal (2002) and Patel (2005) reported non-additive type of gene action for oil content.

The estimation of *gca* effects (Table 2) showed that among the female parents, SKP 106 was the best general combiner followed by Geeta, SKP 42 and VP 1. The line, SKP 106 was good combiner for days to flowering, number of capsules on main raceme, oil content and total seed yield. For remaining characters, SKP 106 was a good to average combiner except plant height and 100 seed weight. The female, SKP 42 was a good general combiner for plant height and 100 seed weight.

Among the males, SKI 294, the early duration male exhibited good combining ability for plant height. Another short duration male parent, SHB 299 was a good combiner for length of main raceme with good *gca* in positive direction for days to maturity, days to flowering, plant height and number of nodes up to main raceme. The SKI 232 was the most desirable parent for number of capsule on primary spike. The JI 273 was a good general combiner for length of main raceme and 100 seeds weight with positive *gca* for number of effective spikes. The male 1-21 had high *gca* for oil content, length of main raceme and 100 seeds weight. The most desirable parents with good general combining ability effects for number of capsules on main raceme and seed yield/plant were SKI 294 and JI 273, respectively.

For comparative study, most promising hybrids having high specific combining ability effects for seed yield are given in table 3. The top hybrid (SKP 106 x PCS 124) exhibited significant *sca* effect in desired direction for total seed yield/plant and number of effective spikes/plant. The second hybrid, SKP 106 x SKI 294 had significant *sca* effects in desired direction for total seed yield, number of capsule on primary spike and length of main raceme. Another hybrid having high *sca* effects for total seed yield was Geeta x SKI 192 registered significant *sca* effects in desired direction for number of effective spikes/plant and days to flowering. The fourth hybrid SKP 106 x GC 2 having high *sca* effect for total seed yield showed significant *sca* in desired direction for length of main raceme, number of capsules on raceme and days to flowering. The fifth hybrid having good *sca* effects for total seed yield, length of main raceme and oil content was SKP 106 x SH 41.

Estimates of variance due to *gca* and sca revealed that non-additive gene actions were involved in inheritance of all the traits. Under such situation exploitation of heterosis hybrid is more useful in future.

Table 1 Analysis of variance (mean square) for combining ability, estimates of components of variance and their ratios for different characters in castor

Source of variation	d.f.	Days to 50 % flowering	Days to maturity	Plant height	No. of nodes upto main raceme	Length of main raceme	No. of capsules on main raceme	No. of effective branches/plant	100 seed weight	Oil content	Total seed yield/plant
Females	3	133.61	510.73*	1541.75**	11.25**	147.82*	149.99	12.12**	67.60**	10.18**	2908955.**
Males	9	23.84	85.18	546.74**	4.68*	114.62*	92.40	1.97	10.06	6.48**	412680
Females x Males	27	33.94**	132.75**	116.61**	1.65**	45.75**	104.94**	1.63	4.66**	1.34**	305578
Error	39	1.563	10.35	6.91	0.38	4.50	4.47	0.35	0.85	0.45	502382
$\sigma^2 gca$		1.18	14.82	11.12	0.086	8.65	16.30	1.02	0.30	0.24	213906
$\sigma^2 sca$		142.06	832.96	348.64	7.334	136.13	512.46	7.51	15.96	4.02	1199848
$\sigma^2 gca/\sigma^2 sca$		0.008	0.018	0.032	0.012	0.064	0.032	0.136	0.019	0.061	0.178

*, ** significant at P=0.05 and 0.01% level, respectively

***Table 2* Estimates of general combining ability effects of the parents for various characters in castor**

Source of variation	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of nodes up to main raceme	Length of main raceme	No. of capsules on main raceme	No. of effective branches/plant	100 seed weight (g)	Oil content (%)	Total seed yield/plant
Female										
VP 1	-3.037**	-4.35**	-11.095**	-0.693**	-3.638**	-1.692**	-0.54**	-2.028**	-0.954**	-459.75**
Geeta	2.813**	6.25**	9.665**	1.058**	0.203	-0.633	0.21*	0.2	0.594**	73.00
SKP 42	1.313**	1.95**	-1.905**	-0.072	0.493	-1.713**	-0.68**	2.383**	-0.136	-75.75
SKP 106	-1.087**	-3.85**	3.335**	-0.292**	2.942**	4.037**	1.01**	-0.555**	0.496**	462.50**
SEm.±	0.2663	0.6406	0.6945	0.1352	0.4651	0.4685	0.1421	0.2193	0.2077	145.51
Male										
SKI 192	-0.112	-1.65	-4.82**	-0.217	-4.207**	-3.058**	-0.33	-0.237	-0.667*	79.12
SKI 215	3.013**	3.725**	7.305**	0.608**	-0.457	-3.032**	-0.005	0.126	-0.732*	76.62
SKI 232	-1.987**	-5.025**	-3.77**	0.183	1.067	4.992**	-0.53*	-0.793*	0.037	-552.12*
SKI 294	-2.487**	-3.025**	-2.47*	0.333	0.542	0.718	0.12	0.351	-0.494	81.00
SKI 299	-1.987**	-2.275*	-3.52**	-0.068	2.392**	1.543*	0.52*	-0.114	-0.495	-58.37
SH 41	0.013	0.975	7.68**	0.082	0.193	0.267	-0.28	-0.263	0.292	47.25
1-21	1.388**	4.6**	15.78**	1.458**	4.793**	-0.708	0.195	1.823**	2.136**	48.50
JI 273	0.887	2.225*	2.405*	-0.193	5.592**	5.867**	0.47*	1.02**	0.607	58.50
EC-38538	0.387*	-2.275*	-12.395**	-0.818**	-5.432**	-3.957**	-0.855**	0.496	-0.878*	-119.62
PCS-124	0.887*	2.725*	-6.195**	-1.368**	-4.483**	-2.633**	0.695**	-2.41**	0.192	339.12
SEm.±	0.421	1.0129	1.0981	0.2138	0.7354	0.7407	0.2247	0.3468	0.3285	230.08

*, ** significant at P=0.05 and 0.01% level, respectively

Table 3 *Sca* effects of the most promising hybrids for seed yield and other traits

Hybrids	Seed yield/plant	Number of nodes up to main raceme	Length of main raceme	Number of capsules on main raceme	Number of effective branches/plant	100 seed weight	Oil content	Days to flowering	Plant height
SKP 106 x PCS 124	394.4	1.217**	-0.817	-0.388	0.695**	-2.41**	0.53	0.887*	-6.195**
SKP 106 x SKI 294	412.5	0.117	5.957**	5.163**	0.12	0.351	-0.384	-2.487**	-2.47
Geeta x SKI 192	771.4	-0.282	-2.453	-9.492**	1.49**	-1.853*	1.137	-2.438**	-2.69
SKP 106 x SKI 299	446.9	0.418	5.007**	14.138**	0.52	-0.114	0.957	-1.987**	-3.52**
SKP 106 x SH 41	323.8	-0.032	2.608	-1.888	-0.28	-0.263	0.53	0.013	7.68**

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Heterosis for seed yield and its components over environments in castor, *Ricinus communis* L.

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Abstract

Forty eight F_1 hybrids and their parents (4 pistillate lines and 12 monoecious lines) were evaluated to study extent of heterosis and standard heterosis for seed yield and other important characters over three environments within crop duration. The parents and hybrids responded differently to environments for their *per se* performance for most of the characters studied. The estimates and magnitude of various heterotic effects varied with crosses irrespective of characters. Inconsistent performance of most of the hybrids across the environments for all the characters under study revealed that parental genes, and their combinations were susceptible to environmental variation, which is general feature of polygenic inheritance. About two thirds of hybrids registered significant and positive hete,obeltiosis for seed yield. The hybrids *viz.*, SKP 24 x SKI 270 (108.02%); VP 1 X DCS 47 (102.19%); Geeta x SKI 147 (94.30%); Geeta x SPS 44-1 (75.5%) and SKP 84 x DCS 47 (75.35%) and SKP 24 x SKI 270 (40.9%) registered significant standard heterosis. The heterotic effects for seed yield might have resulted from direct effect of number of capsules/plant, shelling outturn and test weight of 100 seeds. Accordingly heterotic effects for seed yield could be outcome of indirect effect of effective length of primary spike, number of capsules on primary spike, number of secondary spikes/plant and number of tertiary spikes/plant. The magnitude of heterobeltiosis was negative for development characters leading to earliness. It was also negative for growth attributes related to plant stature, for seed yield and yield component characters it was positive; for seed quality characters, seed size and oil content, magnitude of heterobeltiosis was negative. The pistillate lines, VP 1 and SKP 84 and monoecious lines, DCS 47 and SKI 270 may yield promising cross combinations with other genotypes/parents.

Keywords: Heterosis, heterobeltiosis, polygenic inheritance, pistillate line, monoecious line, castor

Introduction

Heterosis was well exploited in castor with availability of pistillate line. India is the pioneer of castor hybrid. Castor crop has wide range of sowing period, it is sown from mid August to end of October in Gujarat. Thereby it could be adjusted with different cropping sequence/ system.

Castor is sensitive to environmental differences, particularly fertility status of soil, moisture availability and sowing period. Therefore, it is highly essential to examine the performance of new hybrids over a large range of environments. In consideration to this, heterotic performance of 48 F_1 hybrids was studied in different environments within the sowing period at a single location.

Materials and methods

The experimental material comprised of four pistillate lines, 12 inbreds and their 48 F_1 crosses was evaluated in randomized complete block design, replicated thrice. An experimental unit was of single row of 7.2 m length. Total 12 plants were accommodated within the experimental unit with 120 cm and 60 cm inter and intra row spacing, respectively. The parents and hybrids were randomized separately in each replication. The experiments were sown on three different sowing dates with irrigation schedules as under at Regional Research Station, Anand Agricultural University, Anand.

Environment	Date of sowing	Irrigation schedule
E_1	01/08/2007	Rainfed
		At two critical stages
E_2	04/09/2007	At flowering, and
		seed/ kernel development stages
E_3	05/10/2007	As and when required

The observations on five randomly selected competitive plants were recorded for five growth attributes, six yield contributing characters, seed yield and oil content. Mean value of different treatments were subjected for estimation of heterotic effects over environments. The heterobeltiosis as well as standard heterosis over the environments were estimated as per Fonseca and Patterson (1968).

Results and discussion

The estimates of mean square due to genotypes were significant and parents and hybrids significantly differed among themselves for all the characters under study. The contrast comparison of parents vs. hybrids was significant for all the characters, thereby revealing possibility of heterotic crosses (Table 1). Mean square due to genotypes x environments, parents x environments and hybrids x environments interaction were significant for all the characters except shelling out turn (%) and oil content (%), revealing both parents and hybrids responded differently to the array of environments. The results on heterobeltiosis and standard heterosis for various characters revealed that the estimates and magnitude of various heterotic effects varied with crosses irrespective of character. Non-consistent performance of most of the hybrids across the environments suggested that parental genes and their combinations were susceptible to environmental variation, which is the general feature of polygenic inheritance. However, a comparative performance of the most five heterotic crosses for seed yield/plant and other studied attributes have been presented in table 2.

The results revealed that crosses SKP 24 x SKI 270, VP 1 x DCS 47, Geeta x SKI 147, Geeta x SPS 44-1 and SKP 84 x DCS 47 depicted above 75% heterotic effects over respective better parent for seed yield, of which cross SKP 24 x SKI 270 exhibited significant standard heterosis, and it was around 41%. The crosses, which had larger estimates of heterobeltiosis for seed yield also had significant and positive heterotic effects for number of capsules/plant, shelling outturn and test weight of 100 seeds. Therefore, heterotic effects for seed yield would be outcome of direct effects of above characters, accordingly heterotic effects for seed yield could be outcome of indirect effects of other attributes like effective length of primary spike, number of secondary as well as tertiary spikes/plant and number of capsules on primary spike. Among the developmental characters, days to 50% flowering, plant height up to primary spike and number of effective branches might have contributed in directly for seed yield.

In respect to top ranking heterotic crosses for seed yield, cross SKP 24 x SKI 270 exhibited the highest heterobeltiosis (108.0%) as well as standard heterosis (40.9%), the said cross depicted the highest heterobeltiosis for test weight of 100 seeds (15.2%) as well as ranked third for number of capsules/plant (64.7%). The cross SKP 84 x DCS 47 (75.3%) also registered significant and positive heterobeltiosis for % shelling outturn (15.4%), number of capsules/plant (61.5%) as well as number of capsules on primary spike (38.5%). In general, the heterotic crosses for seed yield and other component characters could not show significant and desired heterotic effect for earliness and growth attributes for short plant stature.

On the basis of performance of cross combinations, the parents have been identified as promising parents for further breeding programme. The pistillate line VP 1 could be of immense value for imparting earliness, short plant stature, large primary spike, number of effective primary branches/plant, number of capsules on primary spike and oil content, but it should have wilt resistance. The female parent SKP 84 was emerged promising for earliness, short plant stature, number of tertiary spikes, number of effective branches/plant, number of capsules/plant, test weight of 100 seeds and oil content.

Among the male parents, genotype, DCS 47 was promising for seed yield, shelling outturn, number of capsules/plant as well as number of capsules on primary spike and effective length of primary spike. Whereas, male parent SKI 270 also emerged as promising for test weight of 100 seeds, oil content, number of capsules/plant, number of capsules on primary spike, effective length of primary spike and number of nodes up to primary spike. The extent of heterobeltiosis was high in negative direction for days to 50% flowering and maturity of primary spike, number of nodes up to primary spike, shelling outturn, test weight of 100 seeds and oil content. It was high in positive direction for seed yield/plant, number of capsules/plant, number of capsules on primary spike, number of effective branches as well as tertiary branches, and effective length of primary spike. Whereas, it was of equal magnitude for plant height up to primary spike and number of secondary spike/plant.

Table 1 Analysis of variance pooled over environments

Source	d.f.	Days to 50% flowering	Days to 50% maturity of primary spike	Plant height up to primary spike	Number of nodes up to primary spike	Effective length of primary spike	Number of secondary spike/plant	Number of tertiary spike/plant	Number of effective branches/plant
Environments	2	227.69**	334.80**	17503.50**	70.87**	2127.26**	171.17**	94.42**	244.09**
Replications	2 (6)	0.39	1.61	23.23	1.68	2.09	0.27	0.04	1.17
Genotypes	63	288.95**	2293.93**	3023.31**	58.14**	1091.18**	14.59**	13.30**	61.22**
Parents	15	385.28**	1819.04**	6105.51**	96.32**	1627.04**	37.57**	32.70**	160.70**
Lines	03	592.77**	3012.93**	7269.52**	68.74**	2112.66**	85.52**	40.40**	325.36**
Testers	11	342.17**	1651.76**	5272.86**	108.05**	1642.46**	27.50**	31.34**	127.78**
Lines Vs Testers	01	237.04**	77.52**	11772.98**	50.02**	0.51	4.52**	24.65**	28.88**
Hybrids	47	219.76**	2214.38**	2083.90**	44.33**	799.84**	7.51**	7.27**	30.59**
Parents Vs Hybrids	01	2095.72**	13156.15**	942.38**	134.09**	6746.32**	2.39**	5.65**	8.49**
Genotypes x Environments	126	29.85**	51.93**	1195.28**	1.45**	201.99**	6.83**	4.79**	17.22**
Parents x Environments	30	26.89**	70.56**	1156.16**	1.54**	242.74**	6.35**	7.12**	22.47**
Lines x Environments	06	23.27**	29.90**	127.94**	1.32	183.32**	15.62**	7.82**	37.98**
Tester x Environments	22	28.17**	85.43**	1513.13**	1.70**	259.50**	4.37**	7.01**	20.25**
Hybrids x Environments	94	31.48**	46.73**	1214.28**	1.45**	188.86**	7.12**	4.14**	15.49**
Error	126 (378)	1.54	7.98	42.45	0.64	40.63	0.15	0.14	1.13

Table 1 (contd.) Analysis of variance for experimental design pooled over the environments

Source	d. f.	*Number of capsules on primary spike*	*Number of capsules/plant*	Seed yield/plant	*Shelling outturn (%)*	100 seed weight	Oil content (%)
Environments	2	9306.37**	103049.97**	57490.41**	2888.44**	3.90**	18.24**
Replications	2(6)	14.74	460.14	125.60	0.64	0.76	0.19
Genotypes	63	2830.42**	25272.34**	21209.59**	308.21**	113.24**	40.63**
Parents	15	3914.83**	12346.49**	8666.42**	292.05**	211.85**	50.64**
Lines	03	1839.68**	6159.18**	6142.22**	41.79**	23.45**	87.63**
Testers	11	4635.72**	11807.84**	8136.25**	386.86**	282.00**	44.24**
Lines Vs Testers	01	*2210.46***	*36833.61***	*22070.91***	*0.02*	*5.31***	*10.12***
Hybrids	47	*2260.14***	*24219.51***	*20322.87***	*306.43***	*82.58***	*37.53***
Parents Vs Hybrids	01	13367.63**	268642.96**	251033.09**	634.72**	75.79**	36.50**
Genotypes x Environments	126	924.26**	7427.32**	4907.23**	0.51	7.48**	0.04
Parents x Environments	30	858.25**	3892.70**	2022.82**	0.44	6.85**	0.06
Lines x Environments	06	1993.08**	2995.06**	2000.23**	0.09	0.12	0.04
Tester x Environments	22	506.40**	4300.10**	2157.65**	0.58	7.85**	0.06
Hybrids x Environments	94	949.14**	8567.88**	5832.04**	0.52	7.32**	0.04
Error	126 (378)	75.56	554.59	427.48	8.23	0.56	0.60

*, ** Significant at 0.05 and 0.01 probability level, respectively

Table 2 Range of heterosis, top ranking crosses and superior parents

Character	Range of heterosis		Five top ranking crosses				Superior parents
	HB %	SH %	Heterobeltiosis (HB)	Value (%)	Standard heterosis (SH)	Value (%)	
Days to 50% flowering	-30.84 to 9.64	-17.23 to 29.31	SKP 84 X GC 2	-30.84**	VP 1 X DCS 9	-17.23**	SKP 84
			SKP 84 X PCS 124	-26.41**	SKP 84 X GC 2	-10.30**	VP 1
			SKP 84 X SH 41	-25.65**	VP 1 X PCS 124	-9.11**	GC 2
			SKP 84 X DCS 9	-25.34**	VP 1 X EC 38538	-7.33**	PCS 124
			SKP 84 X SKI 192	-24.58**	VP 1 X SH 41	-7.33**	DCS 9
Days to 50% maturity of primary spike	-44.68 to 20.24	-19.59 to 64.13	SKP 84 X GC 2	-44.68**	VP 1 X SH 41	-19.59**	SKP 84
			VP 1 X SH 41	-40.30**	SKP 84 X GC 2	-19.27**	VP 1
			Geeta X SKI 147	-38.08**	Geeta X SKI 147	-11.56**	SKI 147
			SKP 84 X SKI 1 47	-30.08**	SKP 84 X SH 41	-8.24**	GC 2
			SKP 84 X PCS 124	-29.05**	VP 1 X DCS 9	-7.49**	SH 41
Plant height up to primary spike	-45.83 to 49.86	-56.42 to 62.68	VP 1 X GC 2	-45.83**	VP1 X EC 38538	-56.42**	VP 1
			VP 1 X DCS 47	-40.34**	SKP 84 X EC 38538	-41.70**	GC 2
			VP 1 X EB 16	-36.48**	VP 1 X PCS 124	-23.25**	SPS 44-1
			VP 1 X SKI 202	-34.87**	VP 1 X GC 2	-19.31**	
			VP 1 X SPS 44-1	-32.75**	VP 1 X SPS 44-1	-13.11**	
Number of nodes up to primary spike	-36.51 to 12.54	-33.21 to 20.91	VP 1 X EB 16	-36.51**	VP 1 X PCS 124	-33.21**	VP 1
			VP 1 X SKI 270	-35.27**	VP 1 X SKI 270	-32.72**	SKI 270
			Geeta X EB 16	-33.63**	VP 1 X GC 2	-27.31**	
			VP 1 X SPS 44-1	-32.72**	VP 1 X SKI 192	-26.08**	
			VP 1 X SKI 147	-32.66**	SKP 24 X GC 2	-25.95**	
Effective length of primary spike	-21.32 to 45.22	45.63 to 13.48	SKP 24 X EC 38538	45.22**	SKP 84 X SKI 270	13.48**	VP 1
			VP 1 X DCS 47	38.74**	VP 1 X SKI 270	12.96**	SKP 24
			VP 1 X PCS 124	29.51**	VP 1 X DCS 47	12.62**	SKI 270
			SKP 24 X SH 41	26.67**			DCS 47
			VP 1 X SKI 202	24.21**			

Table 2 (contd.) Range of heterosis, top ranking crosses and superior parents

Character	Range of heterosis		Five top ranking crosses				Superior parents
	HB %	SH %	Heterobeltiosis (HB)	Value (%)	Standard heterosis (SH)	Value (%)	
Number of secondary spikes/plant	-67 to 84.40	-60.18 to -8.85	VP 1 X SKI 147	84.40**	-	-	-
			VP 1 X DCS 9	59.15**			
			VP 1 X SKI 270	58.33**			
			SKP 24 X DCS 9	44.92**			
			SKP 84 X DCS 9	41.46**			
Number of tertiary spikes/plant	-78.73 to 283.08	-71.92 to 22.62	SKP 84 X DCS 9	283.08**	SKP 84 X DCS 9	22.66**	SKP 84
			SKP 84 X SKI 147	177.42**	SKP 84 X GC 2	10.34**	SKP 24
			VP 1 X DCS 9	130.99**	SKP 24 X SPS 44-1	16.40**	DCS 9
			SKP 84 X GC 2	109.35**	SKP 24 X SKI 147	00.49**	SKI 147
			VP 1 X SKI 147	92.96**			GC 2
Number of effective branches/plant	-71.33 to 115.02	-61.49 to 2.43	SKP 84 X DCS 9	115.02**	SKP 24 X SPS 44-1	2.43**	SKP 84
			VP 1 X DCS 9	88.28**			VP 1
			VP 1 X SKI 147	73.12**			DCS 9
			SKP 84 X SKI 147	65.31**			SKI 147
			SKP 84 X GC 2	60.34**			
Number of capsules on primary spike	-35.15 to 75.54	-57.40 to 25.18	SKP 24 X DCS 9	75.54**	SKP 84 X SKI 270	25.18**	SKP 84
			SKP 24 X EC 38538	67.95**	SKP 84 X DCS 47	17.37**	SKP 24
			VP 1 X EB 16	46.40**	VP 1 X SKI 270	12.41**	VP 1
			VP 1 X PCS 124	41.02**	SKP 84 X SKI 202	11.20**	DCS 9
			SKP 84 X DC S47	38.42**	VP 1 X DCS 47	10.89**	DCS 47
							SKI 270
Number of capsules/plant	-31.67 to 79.18	-56.59 to 36.40	VP 1 X DCS 47	79.18**	SKP 24 X SKI 270	36.40**	SKP 84
			Geeta X EC 38538	78.31**	SKP 84 X SKI 270	26.77**	SKP 24
			SKP 24 X SKI 270	64.71**			SKI 270
			Geeta X SKI 147	63.61**			DCS 47
			SKP 84 X DCS 47	61.51**			

Table 2 (contd..) Range of heterosis, top ranking crosses and superior parents

Character	Range of heterosis		Five top ranking crosses				Superior parents
	HB %	SH %	Heterobeltiosis (HB)	Value (%)	Standard heterosis (SH)	Value (%)	
Seed yield/plant	-32.78 to 108.02	-61.40 to 40.91	SKP 24 X SKI 270	108.02**	SKP 24 X SKI 270	40.91**	SKP 24
			VP 1 X DCS 47	102.19**			Geeta
			Geeta X SKI 147	94.30**			SKI 270
			Geeta X SPS 44-1	75.50**			DCDS 47
			SKP 84 X DCS 47	75.35**			
Shelling outturn	-29.07 to 15.76	-29.18 to 9.89	SKP 84 X GC 2	15.76**	SKP 84 X GC 2	9.89**	SKP 84
			SKP 84 X DCS 47	15.41**	Geeta X EB 16	9.89**	Geeta
			SKP 24 X SPS 44-1	15.25**	SKP 84 X DCS 47	9.55**	GC 2
			VP 1 X SKI 270	14.73**	SKP 84 X SH 41	9.18**	DCS 47
			Geeta x SPS 44-1	14.02**	Geeta x SPS 44-1	9.17**	SPS 44-1
Test weight of 100 seeds	-31.46 to 15.23	-32.73 to 13.48	SKP 24 X SKI 270	15.23**	SKP 24 X EC 38538	13.48**	SKP 24
			VP 1 X SKI 270	13.42**	SKP 84 X EB 16	2.09**	SKP 84
			SKP 84 X SH 41	11.73**	Geeta X EC 38538	1.65**	Geeta
			Geeta X SH 41	10.39**			SKI 270
			SKP 24 X SH 41	09.76**			SH 41
							EC 38538
Oil content	-15.62 to 5.97	-7.98 to 9.66	VP 1 X DCS 9	5.97**	VP 1 X EC 38538	9.66**	VP 1
			VP 1 X SKI 270	5.47**	VP 1 X SKI 270	8.92**	SKP 84
			Geeta X DCS 9	5.46**	SKP 84 X GC 2	8.48**	Geeta
			VP 1 X SPS 44-1	5.30**	SKP 84 X EC 38538	8.45**	DCS 9
			SKP 84 X GC 2	3.82**	Geeta X SKI 270	5.36**	SKI 270
							GC 2

*, ** Significant at 0.05 and 0.01 probability level, respectively

The magnitude of heterobeltiosis was negative for both the development characters, days to 50% flowering and days to 50% maturity of primary spike. The results were in confirmation with the findings of Mehta et al. (1991), Joshi et al. (2001) and Patel and Pathak (2006).

Large number of crosses depicted significant and negative heterobeltiosis for the growth attributes viz., plant height up to primary spike, number of nodes up to primary spike, number of secondary as well as tertiary spikes and number of effective branches/plant. The above findings were in accordance with results of Dangaria *et al.* (1987), Mehta *et al.* (1991), Joshi *et al.* (2001) and Patel and Pathak (2006). Whereas, for effective length of primary spike, significant positive and negative crosses were numerically at par, which confirmed the results of Dangaria et al. (1987) and Thakker *et al.* (2005).

Magnitude of heterobeltiosis was positive for number of capsules/plant, number of capsules on primary spike and seed yield/plant, and in both directions for shelling outturn. Whereas, for test weight of 100 seeds and oil content, it was negative. The findings were in agreement with the reports of Dangaria *et al.* (1987), Joshi *et al.* (2001) and Patel and Pathak (2006).

The crosses, which registered larger estimates of heterobeltiosis and standard heterosis for seed yield/plant had also significant and positive heterotic effects at least for one or two yield component characters. Therefore, heterotic effects for seed yield could have resulted from direct and indirect effects of various yield contributing characters. However, positive and negative estimates of heterosis for various yield contributing characters could have countered each other for exhibiting high heterotic effect. Hence, it would be difficult to maximize heterosis at a satisfactory level. Therefore, desired level of heterosis for each component characters should be determined to identify superior crosses for yield and its characters.

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Standardisation of DNA isolation protocol in castor, *Ricinus communis* L.

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Abstract

DNA isolation protocol in castor was standardized by optimizing commonly used Cetyl Tri Methyl Ammonium Bromide (CTAB) method. 2X homogenization buffer (10ml) for 3g of leaf material recovered higher amount of DNA as compared to 1X and 3X homogenization buffer. The concentrations of template DNA (100 ng), $MgCl_2$ (15 mM), Taq DNA polymerase (3 U), initial denaturation time (94°C for 2 minutes) and annealing temperature (37°C) were observed to be the vital factors that influenced the pattern of amplified products. The concentration of $MgCl_2$ found to be the most important factor for the unambiguous and reproducible pattern of DNA amplification. The concentration of Taq DNA polymerase at 0.5 units was found to be the most optimum. As such 100 ng template DNA, 2.5 mM $MgCl_2$, Taq DNA polymerase 3U/µl, 200 µM dNTPs, primer 25 pmol and 40 number of cycles were found to be the most optimum conditions for amplification of DNA in castor.

Keywords: DNA isolation protocol, sandardisation, castor

Introduction

Castor (*Ricinus communis* L.) belonging to family Euphorbiaceae is an important non-edible oilseed crop of arid and semi arid regions of India. Castor has multifarious application in the manufacture of wide range of industrial products such as nylon, fibers, engine lubricants, hydraulic fluids, dyes, detergents, soaps, ointments, greases, paints, varnishes and perfumes etc. Consequently, it earns good amount of foreign exchange for the nation. Morphological and biochemical markers manifest the genetic potential with biasness attributable to genotype x environmental interactions, whereas molecular markers are practically unlimited in number and are not affected by environmental factors and/or developmental stages of the plant growth (Winter and Kahl, 1995; Ram *et al.*, 2007). As such DNA based molecular markers could be an important tool for assisting conventional breeding methods. Standardization of DNA protocol is a prerequisite for ascertaining molecular markers and application thereof in molecular assisted breeding.

Materials and methods

The study on standardization of protocol was carried out in the Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat and National Research Centre for Medicinal and Aromatic Plants, Boriavi, Anand, Gujarat. Seeds of 12 diverse genotypes of castor were grown in green house chamber. One-week old seedlings were used for the extraction of DNA. Total genomic DNA was isolated by commonly used Cetyl Tri Methyl Ammonium Bromide (CTAB) method (Doyle and Doyle, 1990). Crude DNA dissssolved in the TE buffer was purified by giving RNAse treatment. Quality of DNA was checked by Agarose gel electrophoresis and quantification was carried out by UV - spectrophotometer.

Results and discussion

DNA extraction: Leaves of one week old seedlings were used for DNA extraction as per commonly used CTAB method (Doyle and Doyle, 1990). Approximately 3g of fresh leaves were homogenized with a mortar and pestle in liquid nitrogen. The homogenized powder was transferred to 25 ml sterile falcon tube with 10 ml of CTAB buffer. The extraction buffer consisted of 2% (w/v) CTAB, 1.4 M NaCl, 20mM EDTA, 100mM Tris HCl pH 9.5 and 0.2% (v/v) -mercaptoethanol. The homogenate was incubated at 65°C for 1hr and then extracted with an equal volume of chloroform: isoamylalcohol solution (24:1). Then it was centrifuged at 10,000 rpm for 20 mts at room temperature (25°C). The upper aqueous phase was pipetted out and mixed with 2/3rd volume of isopropanol. The precipitated DNA was pooled out and washed twice with 70% ethanol, and finally dried in microfuge tube and dried DNA was then dissolved in TE buffer (Tris 10mM, EDTA 1mM pH 8.0).

The results indicated that 2X homogenization buffer (10 ml) for 3g of leaf material recovered higher amount of DNA as compared to 1X and 3X homogenization buffer. The quality of DNA was also excellent. On the other hand, the DNA recovery was low both at 1X and 3X concentration of homogenization buffer. This could mainly be ascribed to insufficient concentration of CTAB in case of 1X while higher concentration of CTAB interfered with DNA recovery in 3X concentration. Consequently, both 1X and 3X concentration of homogenization buffer resulted in lower recovery of DNA. Results indicating 2X concentration of homogenization buffer method to be less efficient for DNA extraction have been reported by Sagha Maroof *et al.* (1984), Doyle and Doyle (1990) and Hasibe and Asly (2009).

PCR amplification: The PCR amplification conditions need to be precisely defined to obtain distinct patterns of amplified products. The crude DNA dissolved in the TE buffer was purified of RNA by giving 2 ml of RNAse/ml of TE treatment followed by incubation at 37°C for one hr. Then 1 ml of equilibrated phenol was added and shook for 10 mts. The resultant mixture was centrifuged at 10,000 rpm for 20 mts and the supernatant was collected to which 75 µl of chloroform: Isoamylalcohol (24:1) was added and again shook for 10 mts followed by centrifugation at 10,000 rpm for 20 mts. Supernatant was collected to which 1/10th volume of sodium acetate having pH 5.2 was mixed. Finally 2.5 ml of chilled ethyl alcohol was added and centrifuged for 5 mts at 10000 rpm. The DNA was spooled out and air dried. After air drying it was dissolved in 200 µl of TE buffer and stored at 4°C for further use.

The quality of DNA was checked by Agarose gel electrophoresis and quantification was carried out by UV - spectrophotometer. For quantification, the stock of genomic DNA was diluted to 1:50 in distilled water and O.D. was measured at 260 nm. The concentration of DNA was calculated as: DNA (µg/µl) = OD260 ×50 × 20.

The quality of DNA was checked on 0.8 % agarose containing 10 µl of Ethydium bromide (1 mg/ml)/100 ml of gel. Genomic DNA (5 µl) from stock was mixed with 2 µl of bromophenol blue tracking dye and was loaded onto the gel. The gel was run at 80v for one hr. The bands were visualized under UV and scanned by gel documentation system. Purity of DNA was checked by UV- double beam spectrophotometer for all the 12 genotypes of castor (Table 1)

The influence of various combinations of template genomic DNA (20ng, 25ng, 50ng, 75ng and 100ng), $MgCl_2$ (1.0, 1.5, 2.0, 2.5 mM), Taq DNA polymerase (0.5, 1.0, 1.5, 3.0 U/µl) and annealing temperature (35, 37, 40, 42, 45 and 50°C) on amplified products indicated that concentrations of template DNA, $MgCl_2$, Taq DNA polymerase, initial denaturation time and annealing temperature were vital factors that influenced the pattern of amplified products. The yield and profile of PCR amplified products varied with the concentration of template DNA. There was a positive visual association of concentrations of DNA with number of bands, with 100 ng concentration giving the best results. However, high concentration of DNA template gave big blots of DNA / some spurious bands. The concentration of $MgCl_2$ appeared to be the most important factor for the unambiguous and reproducible pattern of DNA amplification. In consonance to the present findings, Zangenberg *et al.* (1999), Paredes *et al.* (2002) and Choudhury *et al.* (2008) have also reported that concentration of $MgCl_2$ altered the amount and type of product of PCR reactions. Similar results of PCR amplification that high levels of $MgCl_2$ increased the production of amplified DNA was reported by Pammi *et al.* (1994) in sorghum. The concentration of Taq DNA polymerase at 0.5 units was found to be the most optimum. Pammi *et al.* (1994) also reported that variations of Taq DNA polymerase from 0.19 units to 3:04 units influenced the results only at limiting polymerase levels. As such 100ng template DNA, 2.5 mM $MgCl_2$, 3U/µl, 200 µM dNTPs, primer 25 pmol and 40 numbers of cycles were found to be the most optimum conditions for amplification of DNA in castor. In consonance to the present results, Ahmad (1999) and Basha *et al.* (2009)

have also reported immense impact of concentrations of DNA template, $MgCl_2$, Taq DNA polymerase and reported reproducible amplification results at 1.5 mM $MgCl_2$, 50 ng template DNA and 1.5 units of Taq DNA polymerase per 25 l reaction in chickpea for RAPD analysis.

Annealing temperature of 38 to 40°C was observed to be optimal for producing highest number of reproducible amplification in castor genotypes. Annealing temperature below and above the optimum temperature of 38-40°C resulted in less number of bands in castor. Zangenberg *et al.* (1999) also reported that the lower annealing temperature often resulted in overall increase in non-specific amplification, while the higher annealing temperature ensued in more specific amplification. However, Pammi *et al.* (1994) reported little amplification at 36°C, optimal at 48°C and significant reduction in amplification patterns above 48°C for chickpea RAPD analysis. Similar results were reported by Nkongolo (2003) in PCR amplification of Malawian cowpea landraces.

Thus, it can be concluded that 2X homogenization buffer (10ml) for 3g of leaf material was most appropriate for recovering higher amount of DNA as compared to 1X and 3X homogenization buffer. The concentrations of template DNA (100 ng), $MgCl_2$ (15 mM), Taq DNA polymerase (3 U), initial denaturation time (94°C for 2 mts) and annealing temperature (37°C) influenced the pattern of amplified products. Further, the concentration of $MgCl_2$ appeared vital for the unambiguous and reproducible pattern of DNA amplification. The concentration of Taq DNA polymerase at 0.5 units was found to be the most optimum. As such 100 ng template DNA, 2.5 mM $MgCl_2$, Taq DNA polymerase 3U/µl, 200 µM dNTPs, primer 25 pmol and 40 numbers of cycles were found most optimum conditions for amplification of DNA in castor.

Table 1 DNA quantification using UV- double beam spectrophotometer

Wave length sample	% transmission			% absorbance			DNA concentration (µg/µl)	Protein concentration	Absorbance ratio
	260	280	320	260	280	320			
48-1	75.0	83.7	100	0.125	0.077	0.000	5.1	24.8	1.62
GEETA	74.1	84.0	100	0.130	0.076	0.000	5.4	19.5	1.71
JI-258	75.5	84.4	100	0.122	0.074	0.000	5.0	22.5	1.65
JP-65	76.5	85.6	100	0.116	0.068	0.000	4.8	17.7	1.71
JI-96	75.3	84.8	100	0.123	0.072	0.000	5.1	18.6	1.71
SKP-84	76.2	85.2	100	0.118	0.070	0.000	4.9	19.3	1.69
VP-1	77.3	85.8	100	0.112	0.067	0.000	4.6	19.2	1.67
VI-9	76.9	85.4	100	0.114	0.069	0.000	4.7	20.8	1.65
LRES-17	77.4	85.2	100	0.111	0.070	0.000	4.5	24.6	1.59
JI-35	77.6	85.0	100	0.110	0.071	0.000	4.9	26.9	1.55
TMV-5	71.3	79.7	95.8	0.147	0.099	0.019	5.2	27.2	1.60
SH-72	71.3	78.9	95.3	0.147	0.103	0.021	5.0	31.8	1.54

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Standardization of hybrid seed production techniques in castor for Andhra Pradesh

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Abstract

A field experiment was conducted during winter season of 2009-10 to evaluate the effect of sowing dates, spacings and growth regulators on hybrid seed production of castor hybrid, PCH-111. The parental lines of DPC-9 (female) and CS-1 (male) were sown in 4:1 ratio with three sowing dates and three different spacings. Growth regulators (Ethrel @ 0.1, 0.05 and 0.01 %) were sprayed at 27 days after sowing (DAS) and 47 days after sowing on seed parent to determine their influence on sex expression. Highest seed yield was recorded from September and October sowings with a spacing of 90 cm x 90 cm and 120 cm x 60 cm. Ethrel @ 0.1 % enhanced the seed quality compared to GA_3 treatment and control. Maximum genetic purity (92.7-95.1%) was recorded in September and October sowings with ethrel @ 0.1% spray was very effective for obtaining better quality seed by suppression of interspersed staminate flowers (ISF) in the seed parent.

Keywords: Castor, hybrid, sowing, spacing

Introduction

Castor (*Ricinus communis* L) is an important non-edible oilseed crop grown for its vast industrial uses. India is the world's largest producer of castor seed and meets most of the global demand for castor oil. In Andhra Pradesh, castor is predominantly grown in Mahaboobnagar, Nalgonda, Kurnool, Ananthapur, Prakasam and Warangal districts. Castor is one of the important oilseed crop having high plasticity suiting to wide range of soil environments and capacity to adjust its growth according to moisture availability conditions of the soil. The productivity in Andhra Pradesh is low (440 kg/ha) as against its national average of 1146 kg/ha (Damodaram and Hegde, 2007). The reason for low yields could be growing this crop under rainfed conditions, low input management besides use of poor quality seeds. Though it is easier for farmer to produce true to type seed of good quality high yielding varieties of castor, producing hybrid castor seeds by farmers has remanded a challenge. Castor is a unique crop having different types of inflorescence i.e., monoecious and pistillate and the expression of male and pistillate flowers depends mostly on the environmental and soil factors and hence, the genetic purity of the F_1 hybrid seed prescribed was 85% as per the certification standards. Though, the castor crop is being cultivated in large areas in Andhra Pradesh, its seed is being imported from other states due to very limited seed production of the crop in the state. Hence, it was considered as one of the priority areas of research for the development of hybrid seed production zones within Andhra Pradesh in order to develop seed producers of castor and to supply quality seed to the castor growers in the state.

Hence, a study was undertaken to standardize the dates of sowing, spacing requirement and suppression of interspersed staminate flowers (ISFs) in pistillate lines of castor for quality hybrid seed production. Such works conducted by scientists elsewhere have brought out the best season for castor crop to be sown in their respective regions for realizing higher yields, June 15 in Maharashtra (Dhoble *et al.*, 1987), May in Gujarat (Sukhadia *et al.*, 1992) and June 30 in Madhya Pradesh (Sawarkar and Thakur, 1999).

Materials and methods

Experiment was conducted in a farmer's field of Balapanoor village, Nandyal Mandal, Kurnool district a non traditional area for castor cultivation, as on-farm trials during *rabi*, 2009-10 following split plot design with three replications. Three dates of sowing (1^{st} September, 1^{st} October and 1^{st} November, 2010) and three different spacings *viz.*, 90 cm x 60 cm, 90 cm x 90 cm and 120 cm x 60 cm. Also the growth regulator (Ethrel @ 0.1, 0.05 and 0.01%) were applied at 27 and 47 days after sowing (DAS) on female parent in order to determine their influence on sex expression and quality hybrid seed production. After harvesting the crop, grow out test was conducted to assess the genetic purity (%) of hybrid seed.

Parental lines of PCH-111 castor hybrid, DPC-9 (female) and CS-1 (male) were sown in 4:1 ratio on three dates with three different spacings in order to standardize and maximize the yield of hybrid seed production in castor. The seeds were manually dibbled by following three different spacings (90 cm x 60 cm, 90 cm x 90 cm and 120 cm x 60 cm) with different dates of sowing and the plot size was 6 rows of 9 m length. Other practices were followed as per the recommended package of practices. The observations were recorded on days to 50% flowering, plant height (cm), number of nodes/plant, duration (days), 100 seed weight (g), number of ISF/plant, seed yield (kg/ac) and genetic purity (%).

Results and discussion

The experimental results showed that the days to 50% flowering slightly increased in November compared to September and October sowings irrespective of the spacings adopted (Table 1). Plant height was observed to be more in case of 90 cm x 60 cm spacing with different dates of sowing compared to 90 cm x 90 cm and 120 cm x 60 cm spacing. Due to increased plant height in 90 cm x 60 cm spacing in all three different dates of sowings, the last picking was not done from the quaternary spikes which resulted in yield reduction. The test-weight of the seed was more in September and October sown crop with different spacings while November sown crop recorded less test weight due to reduced seed filling and the seed weight. Maximum seed yield was recorded in September sowing (584 kg/ac and 549 kg/ac) followed by October sowing (572 kg/ac and 548 kg/ac) with a spacing of 90cm x 90 cm and 120 cm x 60 cm, respectively and there was a significant reduction in seed yield in 90 cm x 60 cm spacing. It was also observed that there was significant increase in the tallness of the subsequent branches after secondaries with 90 cm x 60 cm spacing i.e., due to close spacing. It was observed the spacing of 90 cm x 60 cm was not sufficient in the location wherein the soil fertility was very high and hence resulted in poor seed yield in September and October sown crop. However, there was no such observation in November sown crop as it was not possible to harvest any seed from the later order spikes due to increase in temperatures and poor seed setting. Low seed yield was recorded in November sowings irrespective of spacings.

Results indicated that the effect of different dates of sowing showed significant effect on sex expression in castor. More number of ISF/plant was recorded on November sown crop than September and October sowing (Table 2). Number of interspersed staminate flowers on the female plants in September and October sowing were less compared to November sowing and it may be due to increased temperatures in March and April months. Hybrid seed obtained from September and October sowings with different spacings recorded higher genetic purity (92.9-95.4%) compared to November sowing (87.6-89.1%). Ethrel @ 0.1% enhanced the expression of pistillate flowers by suppression of ISF in the seed parent. Ethrel treatment resulted in higher genetic purity due to suppression of ISF and subsequently the selfed plants and maintained the genetic purity.

Similar results were obtained by Ankaiah *et al.* (2010) wherein the September and October sowing recorded higher seed yield and resulted in quality hybrid seed production in castor. It was concluded that September and October sowing with 90 cm x 90 cm and 120 cm x 60 cm spacings were congenial for castor hybrid seed production in order to harvest maximum seed yield.

Table 1 Effect of sowing dates and spacing on yield and yield parameters of PCH-111 castor hybrid seed production

Treatment	Days to 50% flowering (primary)		Plant height (cm)		No. of nodes/plant		Duration (days)		Test weight (g)		Genetic purity (%)		Seed yield (kg)/ac	
D_1S_1	51		72		14		152		27		94.8		476	
D_1S_2	49		70		13		168		27		95.2		584	
D_1S_2	49		69		14		176		28		95.4		547	
D_2S_1	51		72		15		154		28		91.9		440	
D_2S_2	51		69		14		172		26		92.6		572	
D_2S_2	52		64		14		182		27		93.5		548	
D_3S_1	53		63		14		154		22		88.2		290	
D_3S_2	54		60		14		156		23		87.6		323	
D_3S_2	54		57		14		160		24		89.1		316	
	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±
Main	1.39	0.36	1.28	0.33	5.79	1.48	1.05	0.27	2.74	0.70	2.05	0.53	1.80	0.46
Sub	N.S	0.50	2.12	0.69	2.75	0.89	1.51	0.49	2.12	0.69		0.74	1.61	0.52
Sub at same level of main	N.S	0.62	3.77	0.57	5.49	2.57	2.70	0.46	4.01	1.22	4.17	0.91	2.99	0.79
Main at same or different level of sub	N.S	0.79	3.25	1.03	6.92	1.95	2.36	0.74	4.04	1.20	3.81	1.17	2.89	0.87

D_1 - September sowing; D_2 - October sowing; D_3 - November sowing; S_1 - 90 x 60 cm; S_2 - 90 x 90 cm; S_3 - 120 x 60 cm

Table 2 Effect of growth regulators on the expression of ISF of PCH-111 castor hybrid seed production

Treatment	Number of ISF/plant observed in different sowing dates and spacings											
	September				October				November			
	90x60cm	90x90cm	120x60cm	Mean	90x60cm	90x90cm	120x60cm	Mean	90x60cm	90x90cm	120x60cm	Mean
Ethrel @ 0.1%	9	8	7	8	6	8	7	7	8	7	6	7
Ethrel @ 0.5%	9	9	8	9	9	8	8	8	8	7	7	7
Ethrel @ 0.01%	10	10	8	9	9	9	7	8	10	8	8	9
Control	17	19	17	18	16	18	18	17	21	19	23	21

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Increasing productivity by improving pistillate efficiency and seed set in castor, *Ricinus communis* L.

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Abstract

Field experiments were conducted in castor, *Ricinus connunis* L. under rainfed condition during rainy season of 2008 and 2009 at Tapioca and Castor Research Station, Yethapur, Tamil Nadu to study the effect of exogenous application of chemicals on pistillate production efficiency, seed setting % and seed yield. This investigation was carried out with castor varieties *viz.*, TMV5 and TMV 6 and hybrids *viz.*, TMVCH1 and YRCH1. Chemicals *viz.*, gibberlic acid (GA_3) (100 mg/l), Naphthal acetic acid (NAA) (40 mg/l), Salicylic acid (100 mg/l), Ethrel (50 mg/l), Brassinisteroid (0.1 mg/l) and plant growth regulator (PGR) consortia (100 mg/l) were sprayed eight days before initiation of flowering. Among the chemicals tried, irrespective of the genotypes, PGR consortia induced earliness (7 to 13 days) increased number of pistillate flowers (7 to 45 flowers) and developed compact raceme with 92% of seed set. Among the hybrids, YRCH 1 recorded the highest seed yield (1744 kg/ha) followed by TMVCH 1 (1388 kg/ha) in PGR consortia sprayed plot. Among the varieties, TMV 6 recorded the highest yield (1215 kg/ha) followed by TMV 5 (1128 kg/ha) in PGR *consortia treatment.*

Keywords: Castor, PGR consortia, pistillate flowers, seed setting

Introduction

Castor is one of the important non-edible oilseed crops. Globally castor is grown in an area of 1.26 m ha with annual production of 1.14 MT and average productivity of 902 kg/ha. Where, India shares 53% of the area and 70% of the total production with 1392 kg/ha of productivity. Thus, India is the world leader in castor seed production and meets around 90% of the world requirement of castor oil. Annual earning was around Rs. 2000 crores of foreign exchange by exporting 3 lakh tonnes of castor oil (Pathak, 2009). Castor is a sexually polymorphic monoceious species. There is considerable variation both within and among genotypes in the proportion of pistillate and staminate flowers on the racemes and these proportion can also be strongly influenced by environment (Shifriss,1960). Regulation of sex especially improving pistillate flower production by exogenous application of hormones will be of great importance to obtain higher yield and quality (Ramesh *et al.*, 2000). Therefore, the present investigation was carried out to study the effect of exogenous application of chemicals on pistillate production efficiency, seed setting % and seed yield.

Materials and methods

Field experiments were conducted in research farm of Tapioca and Castor Research Station, Yethapur, Tamil Nadu during rainy season of 2008 and 2009. The experiment comprised of five main plots of castor varieties, TMV5 and TMV6 and hybrids TMVCH1 and YRCH1 and subplots of treatments in different chemical sprays *viz.*, GA_3 (100 mg/l), NAA (40 mg/l), Salicylic acid (100 mg/l), Brassinisteroid (0.1 mg/l), Ethrel (50 mg/l) and PGR (Plant Growth Regulator) consortia (100 mg/l) and control (without spray) was laid out in split plot design and replicated two times. Normal recommended package of practices was followed. The chemicals were sprayed to all the varieties and hybrids for eight days before flower initiation. Observations on five randomly selected competitive plants were recorded for number of pistillate flowers and seed setting %. Days to 50% flowering for assessing earliness and seed yield were recorded on plot basis. The recorded data statistically analysed as per Panse and Sukhatme (1961).

Results and discussion

Days to 50% flowering: All the varieties and hybrids of castor showed their positive responses to the application of different chemicals on induction of earliness in terms of days to 50% flowering. Among the hybrids, YRCH 1 responded well than TMVCH 1 (Table 1). Originally the days to 50% flowering in TMV 5 was 51 days after sowing (DAS), TMV6 was 64 DAS, TMVCH1 was 54 DAS and YRCH1 was 58 DAS. Among the chemicals, PGR consortia sprayed plants attained 50% flowering by 8.5, 7.0, 9.0 and 13.5 days early in TMV5, TMV6, TMVCH1 and YRCH1, respectively followed by salicylic acid sprayed plants. Datta and Nanda (1985) reported that the application of salicylic acid has promotery effects on individual free aminoacids, protects nitrate recutase activity and prevents protein degradation. This promoter effects help to initiate and development of floral buds. It can be suggested that PGR consortia contained this type of floral initiation hormones which leads to induce early flowering.

Number of pistillate flowers/spike: Among the genotypes, YRCH 1 recorded more number of female flowers (74.5) followed by TMVCH 1 (31), TMV 6 (18.5) and TMV 5 (28) under non-spray condition than other entries. Among the treatments, sex differentiation to femaleness was highly induced by PGR consortia (119) followed by nitrobenzene (113.5), salicylic acid (111) and GA_3 (96.5) in YRCH 1 (Table 1). Jaiswal and Aravind kumar (1990) reported that at the onset of flowering, arginine was present only in male flowers while leucine appeared only in female flowers. PGR consortia and nirtrobenzene could be induced leucine level in floral primordia. This might be the reason for improving pistillate efficiency in castor.

Seed setting %: All the genotypes showed positive and significant response with regard to seed setting % in all the treatments compared to control (Table 2). Among the treatments, PGR consortia increased the seed setting as compared to control in all the genotypes The seed setting % increased by PGR consortia ranged from 61.9 to 91.8 among genotypes studied. Shifriss (1961) reported that castor is a long day plant. This long day condition and moderate temperature promote femaleness. High temperature and short day condition promote male tendency. Some hybrids, varieties and pistillate lines are naturally having 90-95% pistillateness. But all these pistillate flowers could not changed into capsules due to low seed setting % and malformation under high temperatures. Shifriss (1956) opined that high temperature of 40°C or above for even relative short day period results in blasting of flowers and poor seed set in castor. PGR consortia may act as a substitute for long day conditions and stimulate the action of long days and improve seed setting and maintain compact raceme even under unfavorable condition.

Table 1 Effect of foliar application of chemical on days to 50% flowering and pistillate flowers

Main plot / Sub plot	TMV5		TMV6		YRCH1		TMVCH1	
	Days to 50% flowering	No. of pistillate flowers	Days to 50% flowering	No. of pistillate flowers	Days to 50% flowering	No. of pistillate flowers	Days to 50% flowering	No. of pistillate flowers
Control (No Spray)	50.5	28.0	63.5	18.5	57.5	74.5	54.0	31.0
GA_3 50 mg/l	48.5	24.5	61.5	29.5	55.5	96.5	46.5	47.0
NAA 40 mg/l	46.5	29.0	62.5	25.0	55.0	83.5	48.0	47.5
Salicylic acid 100 mg/l	45.0	29.5	58.5	30.0	44.0	111.5	44.5	40.0
Brassinosteroid 0.1 mg/l	52.0	28.5	60.0	29.0	52.5	75.5	52.0	51.0
Nitrobenzene 100 mg/l	46.0	26.5	59.0	26.5	45.0	113.5	46.5	52.5
Etheral 50 mg/l	52.5	27.5	61.5	22.5	51.5	74.0	49.5	48.0
PG consortia	42.0	35.00	56.5	33.5	44.0	119.0	45.50	55.50

	Days to 50% flowering			No. of pistillate flowers	
	SEd	CD (P=0.05)		SEd	CD (P=0.05)
M	0.49	1.56	M	0.28	0.90
T	0.80	1.65	T	1.02	2.09
M at T	1.58	3.42	M at T	1.93	4.00
T at M	1.61	3.30	T at M	2.04	4.18

Seed yield: All the genotypes and different chemical treatments were highly significant from each other in their effect on seed yield (Table 2). Among the hybrids, YRCH 1 recorded the highest seed yield (1744 kg/ha) followed by TMVCH 1 (1388 kg/ha) in PGR consortia sprayed plot. Among the varieties, TMV 6 recorded the highest yield (1215 kg/ha) followed by TMV 5 (1128 kg/ha) in PGR consortia treatment. Maintenance of balanced hormones leads to desire modification and finally increases economic yield in crop plants (Mallika Vanangamudi and Kalarani, 2001).Similar findings were also reported by several researches in castor (Mary Varkey *et al.*, 1982; Ramesh *et al.*, 2000 and Sujatha *et al.*, 2007).

PGR consortia developed at TCRS, Yethapur increased seed yield when sprayed at 8 days before appearance of flowering in castor genotypes. PGR consortia is a hormonal mixture. Exogenous application of hormones changes endogenous level of naturally occurring hormones and allows desired change.PGR consortia could maintaine hormonal balance in the crop plants and initiate flowering, induced femaleness, improved seed set and increased seed yield.

It is concluded that the response of plant hormones vary with genotype. Even a single genotype responds differently depending on its age, environmental conditions, physiological stage of development and nutritional status. As for as PGR concerned, the growing conditions did not affect its action but its effectiveness mainly depend on genotype and stage of treatment in relation to plant growth.

Table 2 Effect of foliar application of chemicals on percentage of seed setting and seed yield

Main plot / Sub plot	TMV5		TMV6		YRCH1		TMNCH1	
	Per cent seed setting	Seed yield (kg/ha)	Per cent seed setting	Seed yield (kg/ha)	Per cent seed setting	Seed yield (kg/ha)	Per cent seed setting	Seed yield (kg/ha)
Control (No Spray)	61.9	957	67.8	983	75.0	1399	68.9	991
GA_3 50 mg/l	79.8	1051	80.4	1111	86.3	1585	84.9	1228
NAA 40 mg/l	77.5	1041	81.8	999	82.3	1552	85.4	618
Salicylic acid 100 mg/l	73.3	1059	82.9	1191	87.9	1565	86.2	1265
Brassinosteroid 0.1 mg/l	72.9	997	46.1	998	80.6	1494	82.8	1009
Nitrobenzene 100 mg/l	75.8	1110	84.0	1201	89.6	1698	86.6	1300
Etheral 50 mg/l	78.1	1036	81.4	1011	82.3	1562	83.7	1202
PG consortia	81.6	1128	85.4	1215	91.8	1744	89.2	1388

	Per cent of seed setting	
	SEd	CD(P=0.05)
M	0.41	1.31
T	0.87	1.79
M at T	1.68	3.57

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Development of designer seed for improving early emergence and establishment in castor, *Ricinus communis* L .

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Abstract

Laboratory experiment was conducted at Tapioca and Castor Research Station, Yethapur, *Tamil Nadu to develop* designer seed for increasing seed quality characters *viz*., speed of emergence and establishment in castor under rainfed conditions. The investigation was conducted with YRCH1 castor hybrid with different pre-sowing seed treatments. Among the seed treatments, the castor seeds designed with polykote (red) @ 3 ml + carbendazim (5 g) + imidacloprid (5 g) + *Pseudomonas* (4 g) + *Azospirillum* @ 20 g/kg of seeds recorded the maximum germination (85%), root length (11 cm) shoot length (9.1 cm) and vigour index (941).

Keywords: Castor, designer seed, seed germination, vigour index

Introduction

Quality seed is the most basic input for agricultural output and accounts for 25-30% of yield increase. However, lack of quality seed continuous to be one of the greatest impediments to bridge the vast yield gap. Even with ideal conditions of soil, water and climate, maximum crop yield and quality could not be obtained with inferior seed. Low quality seeds compromise the proper plant stand, influencing directly the productivity of crop. High quality seed is the key to successful agriculture. Each and every seed should readily germinate and produce a vigorous seedling ensuring high yield. In dry land agriculture, drought resistance of the plant is one of the very important factors to get higher yield. Castor is an important non-edible oil seed crop of the arid and semi-arid regions of the world. India is the world leader in castor seed production and meets about 90% of the world's requirement of castor oil earning about Rs. 2000 crores of foreign exchange (Pathak, 2009).

All the modern day castor hybrids are semi-dwarf and are highly productive under irrigated ecosystem. These hybrids are, however, not that much productive under rainfed ecosystem as they lack drought tolerance. In Tamil Nadu, majority of the castor area is in rainfed areas with limited irrigation possibilities. Drought, pest and diseases are the major production constraints for castor in such situation. In this context, the present investigation is proposed to develop castor designer seed to enhance seed quality *viz*., speed of emergence and establishment and seed yield and to study the effect of different pre-sowing seed treatments on seed quality. Designer seed is an integrated pre-sowing seed treatment that involves addition of nutrients, plant protectants and bioinoculants.

Materials and methods

The laboratory experiment was conducted at Tapioca and Castor Research Station, Yethapur, Salem, Tamil Nadu during 2009 in randomized block design with three replications. The treatment details are presented in table 1. Emergence of 2 mm of radicle from the seed coat was taken as criteria for germination (Goswami and Baruah, 1994). Seed germination % was recorded on the 2nd, 4th, 6th, 8th and 10th day after sowing. Root length (cm) of seedlings was measured on five randomly selected seedlings in each replication on 7th day after sowing (DAS) and the mean was taken. The shoot length (cm) of the seedlings was measured on five randomly selected seedlings in each replication. On 7th day, the mean was computed. Vigour index (VI) was worked out according to Abdul Baki and Anderson (1970). VI = Germination % x (root length + shoot length). The data were analysed as per Panse and Sukhatme (1961)

Table 1 Effect of treatments on germination, root length, shoot length and vigour index

Treatments	Germination (%)	Root length (cm)	Shoot length (cm)	Vigour index
T_1 : Dry seed	60	9.4	6.1	570
T_2 : Seed soaking with water	81	9.6	9.0	813
T_3 : Seed fortification with KCl	69	9.6	8.6	677
T_4 : Polykote (red)+ Imidachloprid 5gm + Carbendazim 5gm + *Pseudomonas fluorescens* 4 g+*Azospirillum* 20 g	85	11.0	9.2	941
T_5 : Polykote (black)+ Imidacloprid 5gm + Carbendazim 5gm+ *Pseudomonas fluorescens* 4 g+ *Azospirillum* 20 g	65	10.3	7.8	687
T_6 : T_3+T_4	80	10.1	8.5	817
T_7 : T_3+T_5	62	10.0	8.8	636
SEd	4.23	1.36	0.81	120
CD (P=0.05)	9.21	2.97	1.75	263

Results and discussion

Germination percentage of treated castor seeds differed significantly due to treatments. Among the treatments, T_4 recorded the highest germination % (85). The root length of seedlings differed significantly due to treatments. The maximum root length (11 cm) was measured in T_4 and minimum (9.4) in T_1. Similar results were reported by Jeyanny *et al.* (2007) and Hagiwara and Imura (1991) in rice. The shoot length of seedlings differed significantly due to treatments. The treatment T_4 registered maximum shoot length (9.2 cm) while T_1 had the minimum shoot length of 6.1 cm (Table 1).

The vigour index was significantly differed between treatments (Table 1). Seeds of T_4 recorded maximum vigour index (941). The dry seed (T_1) recorded the minimum value (570). In ISTA (1976) it was quoted that the pre-sowing treatment with chemicals and water improves germination % and vigour index due to increased cytochrome oxidase activity. Basu (1994) also reported that pre-sowing seed treatment with nutrients, biofertilizers and pesticides could modify the physiological and biochemical nature of seed so as to get the characters that are favourable for drought resistance pest and disease resistance. These might be the reason to improve germination % and vigour index in the present investigation. So it is concluded that, the castor seeds designed with polykote (red) @ 3 ml + carbendazim (5 g) + imidachloprid (5 g) + *Pseudomonas* (4 g) + *Azospirillum* @ 20 g/kg of seeds can increase germination per cent, root length, shoot length and vigour index.

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Variability for essential DUS characteristics in released varieties and hybrids of castor, *Ricinus communis* L.

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Abstract

The protection of plant varieties is based on the establishment of distinctiveness (D), uniformity (U) and stability (S) of essential characteristics listed in the crop specific guidelines. The information on range of character expression in released cultivars is essential for the grant of rights through the establishment of distinctiveness. In this context, nine released varieties and ten hybrids of castor were characterized in accordance with the DUS guidelines. The frequencies for expression of different states of essential characteristics are discussed. The information generated on range of variability will be valuable for comparison of newly developed cultivars.

Keywords: Castor, DUS characteristics, variability

Introduction

Castor (*Ricinus communis* L.) is an important industrial oilseed crop globally. India is a key producer of castor in the world with 0.8 m. ha of area and production of 1.0 m. tonnes (Damodaram and Hegde, 2007). Breeding initiatives have resulted in the development of many improved varieties and hybrids (DOR, 2003; Lavanya and Mukta, 2008). With the enactment of Protection of Plant Varieties and Farmers' Rights (PPV & FR) Act, 2001 for grant of protection to plant varieties based on their distinctiveness (D), uniformity (U) and stability (S), the information on range of character expression in the released varieties and hybrids of castor is necessary. Crop specific guidelines form the basis of DUS characterization of the reference as well as the candidate varieties. The draft guidelines for the conduct of test for distinctiveness, uniformity and stability for castor were formulated in 2006 (Chakrabarty *et al.*, 2006) and have been finalized and published (Anonymous, 2009). The information generated in the present study will form the basis for distinguishing the candidate variety from the most similar variety.

Materials and methods

The material for the present investigation comprised of breeders' seed of 9 varieties (AKC-1, DCS-9, GC-2, Haritha, Kiran, Kranthi, VI-9, TMV-5, 48-1) and 10 hybrids (DCH-32, DCH-177, GAUCH-1, GCH-2, GCH-4, GCH-5, GCH-6, DCH-519, RHC-1, TMVCH-1) of castor obtained from the respective breeders.

The experiment was conducted at research farm of the Directorate of Oilseeds Research at Rajendranagar, Hyderabad during rainy season of 2004, 2005 and 2006. Each genotype was raised in 10 rows of 6 m length with a spacing of 90 cm x 60 cm. The experiment was laid out in randomised block design with two replications. Recommended agronomic practices and prophylactic measures were adopted for growing a good crop. The test plot design and data recording of 20 essential traits was based on the draft guidelines (Chakrabarty *et al.*, 2006) while states are based on the finalised version of guidelines of DUST on castor given by PPV&FR Authority (Anonymous, 2009).

Results and discussion

The DUS guidelines for castor consist of 30 traits of which 20 are essential characteristics which are marked by an asterisk in the final draft (Anonymous, 2009). The asterisked characteristics are the traits which need to be evaluated for the assessment of distinctiveness. Assessment of variability through the presence of different states of expression among released varieties and hybrids of castor was undertaken and the frequency distribution for various states of characteristics occurring in 9 varieties and 10 hybrids has been presented (Table 1).

Table 1 Frequency distribution for various states of characteristics in 9 varieties and 10 hybrids of castor

Characteristics	Frequency of different states of train	
	Varieties	Hybrids
Leaf : anthocyanin pigmentation of young emerging leaves	absent(2), present(7)	absent(4), present(6)
Leaf : waxi bloom on upper side	absent(2), present(7)	absent(2), present(8)
Leaf : waxi bloom on lower side	absent(0), present(9)	absent(1), present(9)
Stem : waxi bloom	absent(0), present(9)	absent(0), present(10)
Stem : colour (after removal of bloom)	green(2), mahogany(4), red(3)	green(4), mahogany(6)
Stem : type of internodes	elongated (normal) (9)	elongated (normal) (10)
Plant : time of flowering of primary raceme	early to medium(3), medium (5), medium to late(1)	early to medium(4), medium (3), medium to late(3)
Stem : number of nodes on main stem	low(1), low to medium(6), medium(1), medium to high(1),	low(2), low to medium(5), medium (3)
Leaf : shape	flat(6), shallow cup(3)	flat(7), shallow cup(3)
Petiole : surface	smooth(7), rough(2)	smooth(6), rough(4)
Inflorescence: type of flowers on primary spike	monoecious(9)	monoecious(9), pistillate(1)
Inflorescence: spike compactness	loose(1), semi- compact(4), compact(4)	semi- compact(10)
Capsule : spininess	absent (2), dense (7)	sparse (1), dense (9)
Capsule : length	short(6), short to medium(3)	short(7), short to medium(3)
Plant : branching pattern	divergent(9)	divergent(10)
Seed : weight of 100 seeds (g)	low to medium(6), medium (1), medium to high (2)	low to medium(4), medium (4), medium to high (2)
Seed: shape	elongated(1), oval(8)	elongated(2), oval(8)
Seed: coat colour	dark brown((9)	light brown (1), dark brown (9)
Seed : mottling	high (9)	high (10)

Among the leaf characters, varieties and hybrids exhibited presence and absence of anthocyanin pigmentation of young emerging leaves. Seven varieties possessed triple bloom while only 2 exhibited double bloom. Among the hybrids, one single, one double and 8 triple bloom types were observed. Pink and purple stem colour was not represented among the hybrids and varieties. Among the varieties, there was one cultivar possessing red stem colour while this was absent in hybrids. Different varieties and hybrids with early, medium and late flowering were present. All hybrids possessed low to medium node number. Among the varieties, medium to high node number was also recorded. There were more number of varieties and hybrids possessing smooth petiole surface compared to rough surface. Condensed internodes on stem, deep cup shaped leaf, long capsules and convergent branching were not represented among the varieties and hybrids characterized.

Among the reproductive characteristics, monoecious type of primary spikes were present in all the varieties and nine hybrids, only one hybrid exhibited mostly pistillate expression. All hybrids evaluated possessed semi-compact spikes while all states of expression for this trait were recorded among the varieties characterised. There were no varieties possessing sparsely spiny capsules while non spiny capsules were not represented among the hybrids. High seed weight, square shaped seed and low seed mottling were not represented among the varieties and hybrids characterized. Limited variability for seed coat colour was recorded; there were no cultivars with white, maroon and black seed colour.

The general introduction to the examination of distinctiveness, uniformity and stability and development of harmonized descriptions of new varieties of plants has been described in detail (UPOV, 2001). The information generated on range of variability will be valuable for comparison of newly developed cultivars.

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Breeding behaviour of male lines in castor, *Ricinus communis* L.

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Abstract

Castor is a sexually polymorphic species. Genetic quality of foundation seed of the varieties or male lines of released hybrids is affected by completely male plants or plants with 100% male flowers in all spike orders. An attempt was made in the present study to understand the breeding behaviour of such completely male plants.

Keywords: Pistillate, completely male, castor

Introduction

Castor is a sexually polymorphic species with different sex forms viz., monoecious, pistillate, sex revertants and pistillate with interspersed staminate flowers (ISF) in between pistillate flowers. Sex expression in castor is highly influenced by environmental factors like day temperature, photoperiod, fertility, age of the plant, nutrition, etc. The interaction of sex expression with environmental conditions is documented earlier by Shifriss (1960) and Lavanya (2002) while the role of modifying genes for pistillate character was also indicated by Lavanya (2002).

India is the first country to exploit heterosis in castor by two line breeding based on indigenous, stable S type pistillate line, VP-1 and several other diversified pistillate lines as reported by Lavanya *et al.* (2006). Pistillate expression in hybrid seed production plots is highly unstable and varies with nutrition, irrigation, season and age of the plants. The ideal time of sowing of certified hybrid seed production plots is identified as September second fortnight to October fortnight (DOR, 2009).

The genetic purity of certified hybrid seed also depends on the stability sex expression of pistillate line and tendency of male lines to produce minimum number of male flowers. A male line with high proportion of male flowers (40-100%) in certified hybrid seed production plot ultimately results in low yielding hybrids in commercial cultivation. The tendency to produce high number of male flowers even in released varieties either due to genetic or environmental factors is of serious concern for further spread of the high yielding varieties. An attempt is made in the present study to under stand the genetic nature of plants with 100% male flowers in all spike orders.

Materials and methods

The material has been generated as a part of segregating material involving hybridization between two pistillate lines M-619 and M-584 and 3 male lines SKI-232, SKI-233 and JI-240. The 4 resulting F_1s were selfed to study the F_2s along with the parents in rainy season. About 300 plants of each F_2 were raised in a compact family block design along with both the parents of 50 rows each. Standard agronomic practices were followed to raise the crop. Few plants in each of the 4 crosses showing highly male expression were selfed, in addition to the completely female plants with desired yield component traits. Seed set from highly male plants was low ranging from 5-10 capsules/plant. The progenies were raised in a plant to row to check for the breeding behaviour of the male lines.

Observations on sex expression were recorded by counting the number of floral whorls with male flowers and the total number of floral whorls in every spike order up to 7^{th} order as given by Solanki and Joshi (2000).

$$\% \text{ male flowers} = \frac{\text{Number of male whorls (NMW)}}{\text{Total number of flowering whorls in every spike (TFW)}} \times 100$$

The plants were graded for the sex expression based on proportion of male flowers as: 0=complete female or pistillate, 1-10=highly female, 11-70=monoecious, 71-99=highly male and 100=completely male. In addition, the proportion of male flowers is also quantitatively estimated in %age as follows:

(Total spike length - effective spike length / Total spike length) x 100

Results and discussion

All the 4 F_1s derived from cross between pistillate line x monoecious were monoecious indicating the dominant nature of monoecious character over the pistillate character. In all the 4 F_2s, the segregation for sex expression varied from plants with completely female or pistillate (0% male flowers) to completely male (100% male flowers). Selection pressure was applied from both the extremes ranging from highly/completely female and highly/completely male plants simultaneously. Eleven individual plant selections with 99-99.9% male flowers in all spike orders (5-7^{th}) from 4 crosses were selfed before opening of flowers using butter paper covers. Seed set was low ranging from 5-10 capsules/plant over all spike orders. The progeny was raised in a progeny row trail and graded for the sex expression in F_3 and F_4 generations. In F_3, though initially in the primary spike, monoecious varied 50-80%, gradually with increasing spike orders, all the plants have become highly male (up to 90%) to completely male (100%). Seven selections could not be continued as there was no seed set and plants completely dried at the time of last picking (150 days maturity) (Table 1).

Simultaneous selection for individual plants with low proportion of male flowers (0-10% male flowers) and their selfing for 5-6 generations resulted in 10 homozygous selections. Selfing was done mainly on individual plants with high proportion of female flowers (95-100%) and monoecious plants were completely avoided. These selections were also based on seed yield components like good branching potential, long and effective spike length, high number of effective spikes/plant etc. These 10 selections along with other 140 promising selections were evaluated in a preliminary varietal trial in an augmented randomized block design along with two checks DCS-9 and 48-1 after every 10 rows. Despite the high selection pressure for high female lines, the proportion of male flowers varied from 10-25% with a mean of 17.7% (Table 2).

Table 1 Breeding behaviour of 11 selections from highly or completely male plants

Selection No.	Cross	Pedigree	Proportion of male flowers in different generations (%)		
			F_2	F_3	F_4
2001-15	Cross 1	M-619 x SKI-232	99	80-90	80-100
2001-16		M-619 x SKI-232	99	99	100
2001-24	Cross 2	M-619 x SKI-233	99	80-90	NS
2001-30		M-619 x SKI-233	99	50-90	NS
2001-33		M-619 x SKI-233	99-99.9 *	50-90	NS
2001-105	Cross 3	M-584 x JI-240	99.9	100	NS
2001-106		M-584 x JI-240	99.9	80-90	NS
2001-109		M-584 x JI-240	99.9	100	NS
2001-128		M-584 x JI-240	99.9	80-90	90-100
2001-129		M-584 x JI-240	99.9	80-90	99-100
2001-145	Cross 4	M-584 x SKI-233	99	100	NS

*- male proportion increased from tertiary order of spikes, NS-No seed set on selfing due to complete male lines

Selection for the high male or completely male types bred true to the parents which increased with age of the plant. However, the high female or complete female types did not breed true to their parents even after 5-6 generations of selfing. The extent of heterosis in castor is due to the increase in number of capsules or pistillateness of the spikes as documented by Moshkin (1986) and Weiss (1983). The possibility of developing complete male plants indicates the scope for a three line system in castor.

Genetically divergent parents with extremes of female (complete female) and male (complete male) may increase the heterosis to the desirable extent (>50%). The role of endogenous growth regulators in sex expression has been extensively studied in cucurbits by Karchi and Anneke (1972), Marbhal and Musmade (2007), in mulberry by Kumar *et al.* (1985), musk melon and castor by Lakshmamma *et al.* (2002), Varkey *et al.* (1982), Mohan Ram and Rinaseth, (1980), Ramesh *et al.* (2000) and Gopalakrishna Murthy *et al.* (2003). The role of ethrel or other growth regulators to induce female flowers even in highly male or completely male lines may be explored for the maintenance of male lines. This may open **the avenues** for the exploration of indigenous CMS source in castor as done in other crops like red gram and safflower.

Table 2 Evaluation of advanced selections for seed yield, yield components and proportion of male flowers

Selection No.	Days to 50% flowering	No. of nodes to primary	Plant height (cm)	No. of effective spikes/plant	100 seed weight (g)	Total spike length (cm)	Effective spike length (cm)	Proportion of male flowers (%)
5	52	14.7	74	7	29	39	34	13
6	47	13.7	80	6	29	50	41	18
7	41	15.7	116	6	28	64	56	13
8	48	15.1	129	6	29	47	38	20
9	47	14.1	105	6	29	49	36	25
10	52	15.7	104	5	24	41	34	16
11	61	15.5	70	4	28	38	30	22
12	69	19.7	108	4	33	32	25	24
13	68	14.7	79	4	26	34	31	10
14	58	18.1	118	5	26	35	29	16
DCS 9	46	14.6	84	7	27	29	25	13
48-1	42	13.1	82	6	25	39	34	13
Ci-Vi	39	10.3	75	10	17	19	20	

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Study of genotypes for some quantitative traits in castor, *Ricinus communis* L.

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Abstract

A set of 15 diverse early, medium and late genotypes, including promising and recommended checks *viz.*, Ballia chayan, (7911), Aruna, Kalpi-6 and Type-4 were evaluated at Kalyanpur, Kanpur centre of C.S. Azad University of Agriculture and Technology, Kanpur in rainy season of 2007. Genotype, CK-62 recorded highest seed yield (35.8q/ha) and matured in 170 days. It recorded ICC-57 yielded more than 35 q/ha in the medium group. Genotypes, KC-65 and KC-1 also belong to the same group and recorded high yield (32.3 and 30.1 q/ha), respectively. Variety, Aruna used as a check recorded minimum yield (12.5 q/ha) and matured in 176 days. Cultivar, Kalpi-6 a late variety, matured in 225 days and produced high seed yield (25.8 q/ha). It also had a good number of nodes and spikes.

Keywords: Castor, genotypes, quantitative traits

Introduction

Castor is one of the most important non-edible oilseed crops of the country. Normally, the crop is grown in arid and semi arid tropic soils (Hoshkin, 1986). India, Brazil, China, Russia and Thailand are the major growing states of the world (Pathak, 2009) as sizeable area is grown in these countries. In Uttar Pradesh, chillies+castor is much prevalent inter-cropping system. Also, intercropping with jowar, pearlmillet, mary gold, radish and other crops is a common practice in Uttar Pradesh. Considering the importance of the crop and low productivity compared to the other states the present study was conducted to understand the potential and the perpetuating variability in genotypes.

Materials and methods

A field experiment involving some early, medium and late genotypes was conducted at experimental farm, Kalyanpur, Kanpur of C.S.A. University of Agriculture and Technology, Kanpur to study the yield performance and evaluation in few metric traits. Fifteen diverse castor genotypes were planted in complete randomized block design with four replications. Row spaced at 90 cm while the plant to plant distance was maintained 60 cm apart. Recommended doses of fertilizers were applied to have good growth in genotypes and needed cultural operations were carried out. On physiological maturity, the plot was harvested to evaluate the yield performance and data on ten randomly chosen plants were recorded with respect to metric traits, maturity period, number of nodes/plant and number of spikes/plant. Data were analysed as per Panse and Sukhatme (1961)

Results and discussion

The perusal of data in table 1 showed highly significant differences among the genotypes, signifying the presence of genetic variability. Table 1 showed that the entry CK-62 contributed highest seed yield of 35.8 q/ha over check varieties, Ballia chayan (early), Aruna and Type-4 (medium) and Kalpi-6 (late). Genotypes, ICC-57 and KC-65 yielded 35.5 and 32.3 q/ha seed yield respectively and showed a promise. Genotype, KC-1 contributed 30.1q/ha as against other entries. Probably, high gene order leading to contribute more yield is present in these cultivars. Among the varieties, the performance of Aruna as check was not satisfactory because of low yield which indicates that high yielding genes were not present. Seed yield data indicates that early maturing material showed weak relationship with yield. However, late genotype indicates strong relationship with seed yield/plant.

Days to maturity: Most of the genotypes are in medium group except Ballia chayan and Kalpi-6. Ballia chayan matures in shortest period of 130-140 days and promising to cultivate along with winter season crops particularly wheat, rapeseed mustard, etc. Kalpi-6 (late genotype) matures in 225 days and recently it has been replaced by Chandraprabha which is highly productive and recommended for cultivation in the state of Uttar Pradesh including Bundelkhand areas. In medium maturity group, the range varies from 168-190 days. Genotype, ICC-60 matures in 160 days while, KC-61 matures in 190 days with high seed yield. A clear relationship was observed between days to maturity and seed yield.

Number of nodes/plant: For this trait, the variation was 12.3-23.3 among the 15 genotypes. Castor genotypes KC-65 and CK-61 showed highest number of nodes (23.3) and it was at par. CK-62 possessed high number of nodes/plant and contributed high seed yield too. Genotype KC-1 also produced high number of nodes with high yield. In check entry, number of nodes was poor except Kalpi-6. There was a good relationship between number of nodes/plant and seed yield.

Number of spikes/plant: Number of spikes/plant varied from 3.3-7.5. Genotype, KC-1 showed 6.4 spikes/plant producing high yield of 30.1 q/ha except the check variety Aruna which possessed 7.5 spikes/plant. A strong relationship between number of spikes and seed yield was observed. Most of the entries shows good number of spikes/plant indicating high quantum of variability in the genotypes. Genotypes CK-61, ICC-57 and CK-55 on an average showed more than 5 spikes/plant, means more number of capsules were present to give rise higher productivity. Aruna possessed high number of spikes (7.5) but, produced minimum yield of 12.4 q/ha which clearly showed that there was a weak correlation between number of spikes/plant and seed yield. More number of spikes/plant means more number of capsules/plantproportionately, there will be more production.

Table 1 Seed yield and quantitative traits in castor genotypes

Genotypes	Seed yield q/ha	No. of nodes/plant	No. of spikes/plant	Days to maturity
CK-52	26.9	18.3	5.1	170
ICC-98	19.5	17.3	3.3	175
KC-1	30.1	19.3	6.4	190
CK-55	30.0	18.3	5.3	170
KC-65	32.3	23.3	5.3	172
KC-12	27.9	18.3	4.5	170
CK-61	35.7	23.3	5.3	172
CK-62	35.8	20.0	5.3	170
ICC-57	35.6	18.3	5.5	173
ICC-60	25.9	17.0	5.3	168
DCS-9	28.0	15.3	4.0	174
7911 (c)	17.0	12.5	3.3	140
Aruna (c)	12.5	15.6	7.5	176
Kalpi-6 (c)	25.8	22.3	6.3	225
Type-4 (c)	14.7	12.3	3.3	190
SEm±	0.2			
CD	0.6			
CV%	8.6			

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Correlation and path analysis of yield attributing traits in hybrids of castor, *Ricinus communis* L.

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Abstract

Twenty F_1 hybrids of castor were evaluated during rainy season of 2009 for genetic diversity in respect of seven quantitative traits. Analysis of variance revealed significant differences among the hybrids for all the seven characters studied. High GCV and PCV, high heritability and genetic advance as percent mean were observed for the number of capsules in primary spike, effective spike length and number of spikes/plant. Seed yield/plot showed the significant and positive association with the number of spikes/plant. Number of capsules in primary spike showed a significant and positive association with spike length. Path co-efficient analysis revealed a maximum positive direct effect for the number of spikes/plant on seed yield.

Keywords: Castor, path-coefficient analysis, quantitative traits

Introduction

In India, castor is mainly grown in Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Orissa states accounting for about 90% of area and production. The success of any crop improvement programme essentially depends on the nature and magnitude of the genetic variability present in the crop. The exploitation of heterosis has been an important breeding tool in castor with the availability of stable pistillate lines, exploitation of heterosis on a commercial scale has become feasible and economic (Gopani *et al.*, 1968). Information on the association of plant characters with seed yield is important for a breeder in selecting desirable genotypes. Since the information on those aspects is limited, the present investigation was carried out to gather information on variability, character association and path co-efficient analysis in 20 F_1 hybrids of castor for seven characters.

Materials and methods

The experimental material comprised of 20 F_1 castor hybrids developed by using LRES-17 as a female parent with twenty elite male parents along with two checks were tested in randomized block design with two replications during rainy season of 2008 at Zonal Agricultural Research Station, Hiriyur, Karnataka. Each entry was planted in 3 rows of 10 dibbles keeping 90 cm row to row and 60 cm of plant to plant distance. Recommended package of practices was followed for raising the normal crop. Observations on five randomly selected competitive plants were recorded for seven yields and yield attributing traits. However, days to 50% flowering and seed yield was recorded on a plot basis. Phenotypic and genotypic components of variation were worked out based on the formula given by Lush (1940), Heritability in the broad sense was derived based on the formula given by Hanson *et al.* (1956). Genetic advance was obtained by the formula prescribed by Johnson *et al.* (1955). The method addpted by Burton and De Vane (1953) was used to calculate phenotypic and genotypic co-efficient of variation. The genotypic and phenotypic correlation co-efficient was worked out by following Al-ji-bourie *et al.* (1958) and path co-efficient analysis as suggested by Dewey and Lu (1959).

Results and discussion

Analysis of variance revealed highly significant differences among the genotypes for all the characters indicating the presence of a high amount of variability among the material used in the study. The phenotypic and genotypic co-efficient of variation (Table 1) were highest for the number of capsules in the primary spike, seed yield/plot, primary spike length and number of spikes/plant, suggesting that these characters are under the influence of genetic action, hence these characters can be relied upon for simple selection for further improvement. These results are in consonance with those of Sarwar and Bootar Choudhry (2008) and Patel *et al.* (2010).

Oil content, days to 50% flowering and 100 seed weight recorded a low phenotypic and genotypic co-efficient of variation, as reported by Pathak and Dixit (1992). High heritability coupled with high genetic advance was observed for the number of capsules in primary spike, seed yield/plot, primary spike length and number of spikes/plant. This indicates the lesser influence of environment in expression of these characters and presence of additive gene action in their inheritance, hence, amenable for simple selection. Similar results were reported by Sarwar and Haq (2005) and Sarwar and Boota Choudhry (2008). Barad *et al.* (2009) observed high heritability with moderate genetic advance was recorded for 100 seed weight, days to 50% flowering and oil content indicating that the characters were governed by both additive and non additive gene action.

Genotypic correlation in general was higher than the phenotypic correlation (Table 2) indicating less influence of environmental factors. Number of spikes exhibited highly significant and positive association with seed yield/plot. It indicated that this trait was a reliable indicator. Spike length also exhibited positive and highly significant correlation with the number of capsules. Similar association was observed by Sarwar and Boota Choudhry (2008). Number of spikes showed a negative and highly significant correlation with days to 50% flowering, number of spikes/plant and number of capsules/spike were negatively associated with one another.

The results of the path co-efficient analysis revealed (Table 3) that the number of capsules/plant had maximum positive direct effects on seed yield/plot followed by 100 seed weight and spike number. Similar results were observed by Ramu *et al.* (2005). Therefore these traits may be considered as the principal traits while selecting for seed yield. In other words main emphasis should be placed on the number of capsules, 100 seed weight and number of spikes for improvement of seed yield.

Table 1 GCV, PCV, h^2 and advance (% of mean) for hybrids of castor

	GCV	PCV	h2	A (%) of mean
100 seed weight	9.794	9.926	97.35	19.906
Oil (%)	5.571	5.688	95.93	11.240
No. of spikes/plant	20.495	22.217	85.10	38.948
Primary spike length	28.666	30.092	90.75	56.254
No. of capsules in primary spike	33.558	34.932	92.29	66.410
Days to 50% flowering	9.216	9.260	99.06	18.896
Seed yield/plot	31.467	32.045	96.43	63.654

Table 2 Genotypic (above diagonal) and phenotypic correlation (below diagonal) in castor hybrids

	100 seed weight	Oil (%)	No. of spikes/plant	Primary spike length	No. of capsules	Days to 50% flowering	Seed yield
100 seed weight	1.000	-0.265	0.033	-0.067	-0.311	0.143	0.063
Oil (%)	-0.260	1.000	-0.123	0.112	0.159	0.077	0.214
No. of spikes/plant	0.018	-0.107	1.000	-0.324	-0.132	0.890**	0.591**
Primary spike length	-0.075	0.110	-0.266	1.000	0.790**	0.384	0.120
No. of capsules	-0.299	0.148	-0.069	0.760**	1.000	0.272	0.306
Days to 50% flowering	0.140	0.074	-0.821**	0.376	0.255	1.000	-0.479*
Seed yield/plot	0.068	0.204	0.553**	0.108	0.297	-0.467*	1.000

*, ** significant at 5% and 1% level, respectively

Table 3 Direct and indirect effects of different characters on seed yield in hybrids of castor

	100 seed weight	Oil (%)	No. of spikes/plant	Primary spike length	No. of capsules	Days to 50% flowering	R values
100 seed weight	0.404	-0.078	0.007	0.011	-0.210	-0.070	0.063
Oil (%(	-0.107	0.296	-0.026	-0.018	0.107	-0.038	0.214
No. of spikes/plant	0.013	-0.036	0.212	0.052	-0.089	0.439	0.591**
Primary spike length	-0.027	0.033	-0.069	-0.161	0.532	-0.189	0.120
No. of capsules	-0.126	0.047	-0.028	-0.127	0.673	-0.134	0.306
Days to 50% flowering	0.058	0.023	-0.188	-0.062	0.183	-0.493	-0.479*

*, ** significant at 5% and 1% level, respectively

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G x E and stability studies on castor hybrids for yield and its attributing characters

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Abstract

Stability analysis for castor hybrids along with their parents was carried out over the seasons to know the existence of genotype x environmental (GxE) interactions and stability for yield and its attributes. Analysis of variance revealed significant differences among parents and their hybrids for all the characters indicating diversity in the

material. Presence of significant G x E interactions were noticed for all the characters under study. Significance of G x E (linear) and pooled deviation for various traits suggested importance of both linear and non linear components of G x E interaction with respect of all the characters. Parent VP 1 and SKP-4 found responsive to poor environments for seed yield per plant. SH 72 inbred found stable for the node number whereas TMV-5 was stable for plant height and number of capsules on main spike. SKP-5 as pistillate line and SH 72 as male were found stable for effective branches/plant. SKI 119 was responsive to better environments for capsules per plant of the five high yielding hybrids none was found stable for seed yield/plant. However Geeta x SKI 147 shown stability for some yield attributes and recorded responsiveness in better production environments for seed yield. On the basis of per se performance and stability were yield attributing characters, Geeta x SKI 147, SKP 49 x SPS 43-3 for promising hybrids offering good scope for commercial exploitation.

Keywords: Stability analysis, G x E interaction, hybrids

Introduction

Castor [*Ricinus communis* (L.)] is an important non-edible oil seed crop of arid and semi-arid regions of India. The crop has wide adaptability and is grown in tropical, sub-tropical and temperate regions of the world. The area, production and productivity of the crop in India during 2008-2009 were 8.3 lakh ha, 11 lakh tonnes and 1331 kg/ha, respectively, against 14.3 lakh ha of area, 14.3 lakh tonnes of production and 1000 kg/ha productivity of the crop at the world level (Anonymous, 2008-09). It is an urgent need to have stabilized pistillate, inbred lines and hybrids to fulfill the demand. Hence, the present investigation was taken up to study the G x E interaction and stability of castor hybrids for yield and its attributes.

Materials and methods

The experiment was carried out in L x T mating design (Kempthrone 1957) of 5 pistillate lines (SKP-5, SKP-4, VP-1, Geeta and SKP-49) and 15 inbred lines (SH-72, 48-1, TMV-5, JM-6, SKI-180, SKI-147, DCS-9, SKI-80, HC-8, GC-2, SH-41, DCS-30, EC-103745, SPS-43-3 and SKI-119) at Regional Research Station, Sardarkrushinagar. The Twenty parents (5 pistillate lines and 15 inbreds) and 75 F_1 and national check GCH-4 were grown in randomized block design with three replications. Two experiments (One at the onset of monsoon and other at late monsoon) were taken up each year, keeping plot size of 7.2m long single row accommodating 12 dibbles at 90 cm row to row and 60 cm plant to plant. Totally four environments were created. Five randomly selected plants excluding terminal ones/plot/eplication in all four environments were chosen to record observations of the characters viz., days to flowering, days to maturity, plant height, numbers of nodes up to main raceme, effective branches/plant, numbers of capsules/plant, 100 seed weight, oil content and seed yield/plant. Analysis of variance was performed and stability parameters were worked out following the model proposed by Eberhart and Russell (1966) and Breese (1969). The type of stability was decided on the regression coefficient (bi) and mean values (Finaly and Wilkinson, 1963).

Results and discussion

The magnitude of components of G x E interactions for various traits were estimated and the analysis of variance is presented in table 1. The mean squares due to genotypes and environments were found to be significant for all the characters when tested against pooled deviation. The genotype x environment interaction was highly significant for all the traits when tested against pooled error. This indicated that genotypes interacted significantly in different environments. Mean squares due to genotype x environment (linear) were highly significant for days to flowering, capsule on main spike, effective branches/plant, effective length of main spike, oil content and seed yield/plant when tested against pooled deviation. Performance of genotypes over environments based on regression analysis might not be very reliable. Similar findings were reported by Joshi (1993), Patel (1994a), Patel (1994b) and Tank (2000).

Stability of the pistillate line revealed (Table 2) that all the females had significant deviations from regression for days to flowering days to maturity, capsules on main spike, oil content and 100 seed weight. However, SKP-4 and VP 1 had non-significant deviation from the regression and regression coefficient less than one for seed yield/plant indicating their stability for seed yield under low yielding environments. SKP-5 had non- significant regression, and the deviation from regression for effective length of main spike. SKP-49 performed better in the favourable environment for nodes up to main spike.

Estimation of stability parents of inbred lines revealed that none of the inbred exhibited higher mean, unit regression and non significant deviation from regression for all the 11 characters. Any generalization regarding stability for all the characters was, therefore impossible. However, among inbred SKI 119 had high mean performance for capsules/plant along with regression value more than one and non-significant deviation from regression indicating its responsiveness to a better environment for this important yield attributing character. SKI-147 was stable for effective branches/plant. TMV-5 for plant height and SH-72 for the number of nodes up to main spike recorded nonsignificant deviation from regression.

High heterotic crosses over GCH-4 for seed yield/plant when examined for their stability for seed yield and its components revealed that although they had high *per se* performance but significant deviation from regression indicated that their performance was not predictable under varying environment. Cross Geeta x SKI-147 was stable for effective branches/plant and 100 seed weight as indicated by nonsignificant deviation and responsive to better environment with regression coefficient more than one for capsules/plant, capsules on main raceme. SKP-49 x SKI-180 was stable for effective length of main spike and responsive to the better agronomic conditions for capsules on main raceme. Cross SKP-49 x SPS-43-3 was found responsive to the favourable environment for effective branches/plant. Geeta x HC-8 performed better in the favourable environment for capsules on main spike.

None of the cross combinations recorded high seed yield with higher capsules/plant having unit regression and non significant deviation from regression. However, VP-1 x 48-1 had high mean value, regression co-efficient less than one and nonsignificant deviation from regression for seed yield and capsules/plant indicating environments also. Cross SKP-5 x SKI-80 was stable capsules on main spike SKP-5 x SPS-43-3 for effective length of main spike and Geeta x SKI-147 for number of effective branches/plant and 100 seed weight had non significant deviation from regression indicating their stability. Based on the result, Geeta x SKI-K17 was found to be stable for the number of effective branches, 100 seed weight and responsive to the better environment for capsules/plant, capsules on main spike and effective length of main spike with high heterotic value and good specific combining ability effects. The parents were with good general combining ability for yield and other contributing characters, hence it would be advantageous to exploit this cross in the breeding programme.

Table 1 Analysis of variance showing mean sum of squares for phenotypic stability with regard to different traits in castor

Source	d.f.	Days to lowering	Days to maturity	Plant height	No. of nodes up to main spike	Effective length of main spike	No. of capsules on main spike	Effective branches/ plant	Capsules/ plant	100 seed weight	Seed yield/ plant	Oil (%)
Genotypes (G)	94	167.15** ++	430. 59** ++	762.51** ++	8.03** ++	172.01** ++	617.42** ++	8.49** ++	10047.89** ++	23.73** ++	4893.26** ++	7.59** ++
Environment (E)	3	832.90 ** ++	11196.05 ** ++	20410.03 ** ++	163.09 ** ++	16709.98 ** ++	15998.00 ** ++	135.01 ** ++	383614.88 ** +	351.67 ** ++	85755.06 ** ++	387.94 ** ++
G x E	282	50.44**	140.38**	115.61**	1.73**	35.63**	141.66**	3.07**	4295 79**	3.27**	1547.98**	3.54**
E (Linear)	1	2497.72** ++	33589.28** ++	61230.16 ** ++	489.20 ** ++	50129.47 ** ++	47994.30 ** ++	405.03 ** ++	1150840.40 ** ++	1054.95 ** ++	257268.44 ** ++	1163.37 ** ++
G x E (Linear)	94	60.93** +	146.73**	92.59**	1.64**	52.35** ++	207.69** ++	3.99** +	4955.72**	2.89**	2073.10** ++	6.81** ++
Pooled Deviation (Non-linear)	190	44.72**	135.75**	125.78**	1.75**	10.54**	10.75**	2.58**	3924.09**	3.43**	1271.71**	1.88**
Pooled error	*752*	*0.15*	*0.17*	*29.85*	*0.22*	*7.68*	*15.09*	*0.39*	*212.84*	*0.09*	*71.56*	*0.03*

*, ** Significant at 5 and 1% respectively. When tested against pooled error; +, ++ Significant at 5 and 1%, respectively. When tested against pooled deviation.

Table 2 Mean, regression coefficient and deviation from regression for various traits

Plant height

Parents/hybrids	Xi	bi	S2di
SKP 4	39.62	0.42**	-4.87
VP 1	29.76	0.37**	6.61
SKP 49	44.17	0.49	19.73
TMV 5	62.40	0.76	20.04
GC 2	62.62	0.59**	-4.46
DC 30	50.64	0.45**	17.80
SKP 5 x TMV 5	67.65	1.04	11.91
SKP 5 x DCS 30	76.74	1.09	17.33
SKP 4 x TMV 5	57.68	0.88	12.49

Numbers of nodes up to main raceme

SKP 49	15.55	1.70*	0.55
SH 72	14.03	0.9 .	0.34
48-1	15.49	0.65**	-0.01
TMV 5	13.23	0.36*	0.42
Geeta x HC 8	16.18	2.64**	0.36
SKP 4 x SKI 80	13.28	0.69	0.12
VP 1 x TMV 5	12.50	0.94	-0.02

Numbers of capsules on main spike

TMV 5	34.43	0.83	1.89
DCS 9	37.75	0.44**	10.43
SKP 5 x SKI 80	62.50	1.20	8.20
SKP 49 x GC 2	50.05	1..15	6.56

Effective branches/plant

SKP 5	4.93	0.33**	0.07
SKI 147	8.67	0.82	0.08
SPS43-3	8.00	-0.08**	-0.10
Geeta x SKI 147	9.40	1.54	0.24
SKP 49 x SKI 180	7.41	1.16	-0.05

Effective length of main spike

Parents/hybrids	Xi	bi	S2di
SKP 5	42.13	1.09	1.21
SH 72	34.88	0.90	3.45
GC 2	29.43	0.76**	-0.78
SKP 5 x SPS 43-3	50.78	1.21	4.86
SKP 4 x TMV 5	*40.72*	*1.11*	*4.44*
SKP 49 x DCS 9	44.52	0.86	4.34
SKP 49 x SKI 180	50.12	1.18	2.43

Capsules/plant

VP 1	137.75	0.41**	-25.81
SKI 119	244.33	1.43**	-46.25
Geeta x SKI 147	325.25	1.82**	86.30
Geeta x SKI 180	307.00	1.29**	9.95
VP 1 x 48 -1	283.00	0.34**	8.06

100 seed weight

Geeta x SKI 147	28.42	1.18	0.05

Oil content

Geeta x DCS 9	46.69	2.33**	0.01

Seed yield/plant

SKP 4	51.41	-0.49**	7.39
VP 1	88.34	-0.25**	25.26
VP 1 x GC 2	194.15	1.74**	-26.06
Geeta x DCS 9	172.56	0.62**	-.0.54
VP 1 x 48-1	202,84	0.15**	18.12
VP 1x SPS 43-3	162.71	1.25**	-7.12

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Genetic variability studies in castor, *Ricinus communis* L.

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Abstract

Fifteen genotypes of castor (*Ricinus communis* L.) were evaluated for variability parameter like seed yield and its related characters. The genotypes were evaluated during rainy season of 2009 in randomized block design with three replications at Zonal Agricultural Research Station, Mulegaon Farm, Solapur. The results indicated that significant variation were observed for seed yield and its components. High heritability with high genetic advance and genotypic coefficient of variation were observed for plant height, days to maturity and seed yield, indicating direct selection of these traits were effective. High heritability with moderate genetic advance was observed in number of capsules to primary spike and effective primary spike length. Studies showed that selection of these traits were effective.

Keywords: *Ricinus communis*, GCV, PCV, heritability, GA

Itroduction

Castor (*Ricinus communis* L.) is an important oilseed crop cultivated for its premier oil with manifold uses. Genetic variability is the most important feature of any population and variability present in the population are the pre-requisite in response to selection for crop improvement programme. Selection of superior varieties will be possible only when adequate variability exists in the gene pool. Hence, the insight into the magnitude of variability present in a gene pool of a crop species is of utmost importance to plant breeder for starting a judicious plant breeding programme. The coefficient of variation expressed in phenotypic and genotypic levels are used to compare the variability observed among different characters. A wide range of variation has been reported for seed yield and its contributing character. The heritability estimates aid in determining the relative amount of heritable portion in variation and thus, help the plant breeder in selecting the elite inbreds from a diverse population. Therefore, the present study was undertaken for assessing the extent of genetic variability, heritability and genetic advance in castor genotypes.

Materials and methods

The material for the present study was comprised of 15 castor genotypes including checks obtained from Directorate of Oilseeds Research, Hyderabad. The experiment was conducted at Zonal Agricultural Research Station, Mulegaon Farm, Solapur during the rainy season of 2009. Each genotype was sown in six rows of 6 m length with a spacing of 90 cm x 60 cm in randomized block design with three replications. Five plants were selected from each genotype/replication for recording the observations on seed yield and its component characters *viz*., plant height, days to 50% flowering, days to maturity, number of capsules to primary spike, number of nodes to primary raceme, effective primary spike length, number of effective spikes/plant, test weight and oil %. Analysis of variance and estimates of genotypic and phenotypic coefficients of variation, broad sense heritability and expected genetic gain were worked out by using conventional methods (Falconer, 1981).

Results and discussion

The analysis of variance revealed significant differences for all the ten traits studied (Table 1). The range of variation was high for the characters (Table 2) *viz*., days to maturity (87.7 to 123.3) followed by plant height (84.3 to 122.3 cm), number of nodes to primary raceme (7.7 to 17.7) and seed yield (7.4 to 15.4 q/h), while it was the lowest in the case of number of effective spikes/plant (4.3 to 6.7). In general, PCV values were marginally higher than GCV values indicating the role of environmental variances as reported earlier by Kaushik *et al.* (2007). The characters studied in the present investigation showed moderate to low PCV and GCV values. The magnitude of variation was maximum for the plant height, number of capsules to primary spike, number of nodes to primary raceme, effective primary spike length and seed yield. These results are in accordance with the result of Patel *et al.* (2010). Moderate levels of PCV and GCV were obtained for days to maturity, number of effective spikes/plant and test weight. Prasanthi *et al.* (2009) also reported similarly. However, low values were obtained for days to 50% flowering and oil content as reported by Sujatha *et al.* (2002). However, high variance values alone are not the determining factors of the expected progress that could be made in quantitative traits (Falconer, 1981). It was suggested that the GCV together with the high h^2 estimates would give a better picture of the extent of genetic gain to be expected under selection.

In the present investigation, all the character expressed high heritability ranging from 57.2 to 99%. The highest heritability was recorded by plant height (99%) followed by effective primary spike length (93.9%) and number of nodes to primary raceme (86.2%). The genetic advance was the highest for seed yield (344.4) followed by plant height (45.2), days to maturity (22.4) and number of capsules to primary spike (15.3). While, the genetic advance as % mean was the highest for plant height (58.8%) followed by number of capsules to primary spike (42.2%), effective primary spikes length (41.3%), number of nodes to primary raceme (40.9), seed yield (33.6%) and number of effective spike/plant (22.1%) and rest of the character recorded medium to low genetic advance as % mean. High heritability coupled with high genetic advance as % mean were noticed for the character *viz.*, plant height, effective primary spike length, number of nodes to primary raceme, number of capsules to primary spike and seed yield suggesting the presence of additive gene action controlling these traits. Similar results were reported by Patil *et al.* (1996), Patel *et al.* (2010), Sujatha *et al.* (2002) and Kaushik *et al.* (2007) where heritability was high and genetic advance as % mean was low, as the environment influences these traits. The expression of traits is unstable hence, breeder should not rely on the estimates of heritability alone.

Table 1 ANOVA for seedyield and yield attributes of castor

Character	Mean sum of squares		
	Replications	Treatment	Error
Plant height (cm)	1.742	1466.736**	5.160
Days to 50% flowering	1.156	44.851**	2.227
Days to maturity	2.866	438.628**	23.723
No. of capsules to primary spike	52.156*	212.117**	13.203
No. of nodes to primary reo	4.422	19.565**	0.993
Effective primary spike length (cm)	4.822	144.736**	3.084
No. of effective spikes/plant	0.355	1.755**	0.260
Test weight (g)	6.459	20.833**	1.647
Oil content (%)	45.411**	5.489**	1.095
Seed yield (kg/ha)	13286.51	104511.82**	5826

* Significant at 5% level; ** Significant at 1% level

Table 2 Estimates of variability, heritability and genetic advance in castor

Character	Range		Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability broad sense. (h^2)	Genetic advance	GA as % mean
	Min	Max							
Plant height (cm)	84.3	122.3	492.35	487.19	28.86	28.71	99	45.23	58.82
Days to 50% flowering	45.7	58.7	15.692	13.46	7.36	6.81	85.8	7	13
Days to maturity	87.7	123.3	162.02	138.30	12.23	11.30	85.4	22.38	21.50
No. of capsules to primary spike	23.7	54.3	79.50	66.30	24.55	22.43	83.4	15.32	42.19
No. of nodes to primary raceme	7.7	17.7	7.18	6.19	23.06	21.41	86.2	4.75	40.94
Effective primary spike length (cm)	21.7	46.7	50.30	47.21	21.33	20.66	93.9	13.71	41.25
No. of effective spikes/plant	4.3	6.7	0.75	0.49	16.32	13.23	65.7	1.17	22.08
Test weight (g)	22.6	31.2	8.08	6.39	10.69	9.53	79.5	4.64	17.52
Oil content (%)	46.7	52.2	2.56	1.46	3.20	2.42	57.2	1.88	3.77
Seed yield (q/ha)	7.4	15.4	38721.37	32895.22	19.21	17.71	85.0	344.36	33.62

Heritability in broad sense - Below 25 (Low), 25-50 (Medium) and above 50 (high)

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Studies on varied sex expressions in castor

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Abstract

A study was conducted to understand the pattern of variation among segregating materials of the prebreeding programme in terms of sex expression. Crosses were attempted between three pistillate lines and six staminate plants. The hybrid plants in each combination showed differential sex expression varying from complete male (staminate), interspersed staminate flower (ISF), interspersed pistillate flower (IPF), pistillate, monoecious and monoecious with ISF. etc. The frequency table clearly showed that the sex expression in castor, which is influenced by environment, is highly variable. The influence of different pistillate lines over the expression of staminate character and the significance of the materials studied are discussed in detail.

Keywords: Castor, sex expression

Introduction

Development of complete pistillate lines and the presence of exploitable levels of heterosis for seed yield paved the way for hybrid castor development in India. Subsequently, hybrid vigour was commercially exploited by utilizing female lines namely TSP.10R initially and VP.1 later in Gujarat and the first castor hybrid, GCH.3 (TSP 10R x J1.15) yielded 124 % over the variety under cultivation. Since then, a large number of hybrids have been developed and released for cultivation in India. The introduction of hybrids has resulted in increased area, production and productivity of castor giving India a virtual monopoly in international market.

Castor is normally monoecious with pistillate (female) flowers on the upper portion of the raceme and staminate (male) flowers on the lower part. In normal inflorescence the pistillate flowers occupy about 30-50% of the portion of the spike and the remaining lower portion by staminate flowers. The ideal sex phenotype of a variety or a hybrid should have female flowers from the base of raceme with staminate flowers confined to bottom 2-3 whorls, which is just sufficient to provide required pollen. The proportion of pistillate to staminate flowers in different orders of castor racemes vary within and among genotypes as a result of variations in day temperatures, age of the plant and nutrition levels. High temperature (>32°C) during the crop growth period, low nutrition and higher age of the crop promote maleness while femaleness is more in young plants growing under higher nutrition levels and low temperature. The proportion of female flowers in different order racemes has a strong bearing on ultimate seed yields. In normal monoecious varieties, the percentage of pistillate flowers on racemes is usually highest on main raceme and decreases gradually on subsequent raceme orders. A proportionate increase in number of male flowers related with proportionate decrease of pistillate flowers is highly influenced by seasons. Female tendency is highest in spring/early summer or winter, while male tendency is maximum in mid and late summer. The effect of temperature on the male/female flower ratio was studied. Moderate temperature (32°C) promotes female tendency while high temperature promotes male tendency. It is also related to the age of plant; femaleness being strong in young plants with high level of nutrition while maleness is strongest in old plants and with low level of nutrition. It was found that female tendency increases after severe pruning of well-established plants.

Castor though a typically monoecious type is a sexually polymorphic species. The basic sex forms in castor range from monoecious to pistillate and hermaphrodite forms. Shifriss (1960) classified the sex variants as conventional and unconventional types and described three types of pistillate mechanisms as N type, S type and NES type based on the genetic control of the trait. The S type pistillate castors are being used in the hybrid development programmes but the changing sex expressions influenced by environment are the major bottleneck in hybrid seed production. In the absence of a cytoplasmic male sterility-fertility restoration system in castor, understanding the mechanism of sex expression is a paramount importance as the hybrid seed production is solely depended on the pistillate system. In this context, a study was initiated to understand the pattern of variation among the segregating materials of the prebreeding programme where several sex variants have been recorded.

Materials and methods

Interestingly, among the several cross combinations studied under prebreeding programme, in F_2 generation a high frequency of plants showing complete male flowers (staminate plants) were observed only in combinations where one of the parents is Kiran. Six plants bearing only male flower in the entire spike have been selected in the segregating material of crosses involving variety Kiran as one of the parents. The plants were stable in the expression of only male flowers till the last spike observed and are being maintained under *in vitro* conditions, as sexual propagation is impossible. The materials for the present study included these six staminate plants and three pistillate lines *viz.*, DPC 9, M 574 and Geetha, female lines of highly adapted popular castor hybrids.

Crosses were attempted between the three pistillate lines and the six staminate plants during the rainy season of 2008. The hybrids were evaluated by following randomized block design with three replications during the rainy season of 2009 and winter season of 2009 so as to observe the sex expressions over a period of time (till sixth order spikes). The presence of pistillate and staminate flowers, the type of sex expression and arrangement of flowers in the spike were recorded from individual plant of each combination studied time to time.

Results and discussions

Adequate quantities of hybrid seeds were obtained in each of the 18 combinations irrespective of the staminate plant used. It is important to mention that though all the six staminate plants were found to be stable in sex expressions, they were F_2 segregants and hence, each one is different from each other in other morphological traits. Interestingly, these staminate plants also showed varying degrees of pollen fertility. The hybrids between complete staminate and pistillate plants showed segregation for different morphological traits and hence not uniform as expected in F1 plants in each individual combination. Since, the interest was only to study possible variants in sex expression, the variability in other morphological traits, other than inflorescence, have been neglected.

The hybrid plants in each combination showed differential sex expression varying from complete male (staminate), ISF (interspersed staminate flower), IPF (interspersed pistillate flower), pistillate, monoecious and monoecious with ISF, etc. (Table 1). The frequency of each class mentioned above varied from combination to combination as expected. While studying the influence of different pistillate lines over the staminate character, it was interesting to note that only M 574 with M_1 and Geetha with M_2 showed plants with complete male flowers. Contrastingly, DPC 9 in all the combinations invariably showed plants either towards pistillate or monoecious character but not towards staminateness. High frequency of monoecism (monoecious and monoecious ISF) followed by pistillateness (pistillate and ISF) have dominated when combinations with M 574 and Geetha as the single common pistillate parent were pooled together. However, dominance of pistillateness has been proved beyond doubt whenever DPC 9 was the common pistillate parent. Only in two combinations staminate plants were observed with the frequency of 40-51%. These combinations have been advanced further to study the inheritance pattern of the trait. Interestingly, a new class of sex expression, IPF has been recorded in 7 out of 18 combinations, mostly involving Geetha as pistillate parent where male and female flowers have been arranged in a fashion just opposite to that of ISF. The entire spike is dominated by staminate flowers with a few pistillate flowers interspersed. The frequency table clearly indicates that the sex expression in castor, which is influenced by environment, is highly variable. Two extreme types, pistillate and staminate, have been identified. While the pistillate types survive by changing to ISF expression under different environment so as to perpetuate the progenies, the staminate types get eliminated as the trait seems to be stable and not influenced by environment. However, the role of IPF in maintaining staminate lines has to be established as it was done in the ISF with pistillateness. The intermediate types like IPF, ISF and monoecious types have significant role in maintaining as well as sustaining these special plant types of castor.

The study clearly showed out the varied types of sex expression in castor and their significance. The next step would be to bring out the genetic control and mechanism of these varied sex types of castor. The ideal materials for such a basic study would be a pistillate line and an isogenic staminate line. Substitution BCs have been effected in the selected combinations to develop isogenic staminate and pistillate stocks to understand the genetic control of this trait. The understanding of the genetic mechanism assumes importance as the trait has a very significant role in the success of hybrid seed production.

Rejections of hybrid seed lots due to failing in grow out tests are very common in castor. The genetic purity of the hybrids and their female parents *viz.*, pistillate lines, determined mainly by the environment, the isolation distances and the seed crop agronomy followed (Prabakaran *et al.*, 2009). Though by adopting isolation of the seed crop prescribed for different categories of seeds and proper agronomical practices thereby avoiding stresses particularly moisture and nutrient stresses, one can produce seeds with adequate genetic purity. However, with the changing climate the environmentally sensitive pistillate lines change their sex expression causing havocs in seed production plots leading to rejection and heavy economic losses to the growers. Hence, development of a stable pistillate line is the need of the hour till a CMS-fertility restoration system is identified to make castor hybrid seed production viable.

Table 1 Frequency of sex variants in crosses involving staminate and pistillate plants

Combination		Number of plants observed to be						
Pistillate parent	Staminate parent	Pistillate	ISF	Monoecious	Monoecious ISF	IPF	Staminate	Total
M 574	M2				13	5		18
	M3			2	11			13
	M6		11	1	4			16
	M9		3		3			6
	M1		6	1	1	1	8	17
	M7			1	10			11
DPC 9	M2	5	2	3	10			20
	M3	4	2		11			17
	M6	2	14		4			20
	M9	1	15		2			18
	M1	1	19					20
	M7		7		8			15
Geetha	M2			2	6	4	8	20
	M3			5	14	1		20
	M6		8		10	1		19
	M9		8	2	4	2		16
	M1	1	17					18
	M7				11	6		17

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In planta transformation of castor, *Ricinus communis* L.

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Abstract

Transgenic castor plants have been produced by a tissue culture independent method using *Agrobacterium tumefaciens* transformation procedure. Ten-day-old-seedlings of castor variety (cv. 48-1) were wounded with sterile scalpel blade and immersed in suspension of *Agrobacterium* LBA 4404 strain culture that carries 2301 plasmid with β-glucuronidase p35s GUS INT and plant selectable marker Neomycin phosphotransferase gene (*nptII*). Apical meristems of the differentiated embryo of the germinating seedling were infected with *Agrobacterium*. The first proof of transformability in the T_0 generation was indicated by the GUS histochemical analysis of the plants, at various stages and also with PCR. Four PCR positive plants were recovered. Molecular characterization and GUS expression analysis suggested the feasibility of the method to generate transgenic plants in castor.

Keywords: In planta transformation, castor, *Agrobacterium tumefaciens*

Introduction

Castor (*Ricinus communis* L.), is an important non edible oilseed crop and India with an area of 0.75 m ha. and production of 0.7 m t, is the leading producer of castor in the world. Castor owes its importance to the uniqueness of its oil which is rich (80-85%) in ricinoleic acid, the hydroxyl fatty acid. Castor oil was primarily used for medicinal purposes and as high-quality lubricants for heavy equipment or jet engines.

Genetic improvement of any crop species through genetic engineering techniques requires an efficient *in vitro* regeneration system which is rapid, reproducible and applicable to a broad range of genotypes. However in castor, research efforts for the last three decades have failed to provide a reliable protocol of *in vitro* plant regeneration. Reports on *in vitro* studies in castor suffer from non reproducibility, low multiplication rates and involvement of pre-existing meristems (Athma and Reddy 1983; Reddy *et al.*, 1987; Reddy and Bahadur 1989; Sarvesh *et al.*, 1992; Molina and Schobert 1995; Sujatha and Reddy 1998).

To tackle the problems pertaining to regeneration in castor and certain other recalcitrant crops, alternate methods to minimize or eliminate the steps of regeneration such as *in planta* methods are being standardized. Research with *Arabidopsis* has benefited from the development of high throughput floral transformation methods that avoid plant tissue culture (Azipiroz- Leehan and Feldmen, 1997). *In planta* transformation methods have also been standardized for rice (Supartana *et al.*, 2005), buckwheat (Kojima *et al.* 2000), sunflower (Sankara Rao and Rohini, 1999), safflower (Rohini and Sankara Rao, 2000), peanut (Rohini and Sankara Rao, 2001). The strategy essentially involves *in planta* inoculation of embryo axes of germinating seeds allowing them to grow into seedlings *ex vitro*. These *in planta* transformation protocols are advantageous over other methods because they do not involve regeneration procedures and therefore the tissue culture-induced somaclonal variations are avoided. This paper presents genetic transformation of castor by following *in planta* transformation protocol.

Materials and methods

Seeds of castor variety 48-1, were soaked in water for 1 hr and were surface sterilized with 0.1% $HgCl_2$ for 5 min followed by 3 washes with distill water and later with bavistin 1% for 5 min. The seeds were allowed to germinate on the sterile vermiculite in plastic trays and 1-14 day-old-seedlings were taken as explants for *Agrobacterium* infection. For transformation experiments, disarmed *Agrobacterium* strain LBA4404 with the binary vector pCAMBIA 2301+35s promoter was used. The vector carries neomycin phosphotransferase gene (*nptII*) and β-glucuronidase under the control of Camv 35s promoter. Bacteria was cultured initially in LB medium at 28°C and resuspended in Winan's AB medium (Winans *et al.*, 1988) for overnight at 28°C.

Transformation, selection and recovery of transformants: Seedlings were harvested from vermiculite trays and washed with distill water and meristems were splitted into 2 halves with sterile scalpel blade and imbibed in *Agrobacterium* suspension and shaken in dark for 12 hr at 25°C. After 12 hr, explants were taken out and washed with distill water followed by gentle agitation for 5 min in distill water containing 250 µg/L cefotaxime and transferred directly into pots with soil in green house. For each experiment, 300 explants were inoculated with *Agrobacterium*. The variables tested include, age of the seedlings (0-14 days), bacterial titre (0.1-1.0 OD), use of vir gene enhancer acetosyringone (50-200 µM), wounding type, incubation period, etc. At various stages, the transient expression was recorded by the GUS histochemical assay and the putative transformants were confirmed for the presence of introduced transgene by PCR analysis.

Polymerase chain reaction: Genomic DNA was isolated from the plants using CTAB method (mini prep). PCR was performed with genomic DNA from primary transformants to check the presence of *uid A* gene. The PCR reactions were carried out in a total volume of 10µl containing 100 ng template DNA 1µl, 6.9µl sterile mq water, 1µl 10X PCR buffer, 0.6µl dNTP mix, 0.15µl of the primer set and 0.2µl of taq DNA polymerase (3 U/µl) (Bangalore Genei, Bangalore). PCR was initiated by a hot start at 94°C for 4 min followed by 30 cycles of 1 min 94°C, 30s 60°C, 1 min 72°C. The products were resolved on 1.4% agarose gel at 90 volts.

Results and discussion

Preliminary experiments on the effect of different variables that can enhance the frequency of transient GUS expression were carried out. The variables included bacterial titre (0.2, 0.4, 0.6, 1.0 OD), incubation period (1, 2, 4, 8, 12 and 24 hr), age of explants (2, 4, 6, 8, 10, 12, 14 day-old), acetosyringone, a phenolic compound which acts as an inducer of vir genes (0-200 µM), wounding (pricking with needle, incision on meristematic zone with blade, meristem split into two halves with blade). The effect of all these parameters with the exception of explants and bacterial cell density was found to be non-significant. Transient GUS expression at a bacterial OD 0.6 was 80% while it was 40-50% at 0.2-0.4 OD. The frequency of transformation declined with increasing seedling age, survival of seedlings after subjected to blade injury and incubation in *Agrobacterium* suspension for 12 hr, 2 to 6 day-old-seedlings were not survived. The maximum frequency survival observed from 10 day-old and above. Optimization of the parameters for *in planta* transformation indicated a higher frequency of transformation and plant survival with 10 day-old-seedlings infected with 0.5 OD of bacterial culture containing 100 µM acetosyringone with 12 hr shaking.

Molecular analysis of putative transformants

To confirm the presence of the transgene, GUS histochemical assay was done at different stages. The putative transformants were confirmed using PCR analysis with specific primers

GUS assay: The method of Jefferson (1987) was used to assess the histochemical *Uid A* gene expression in the tissues of primary transformants.

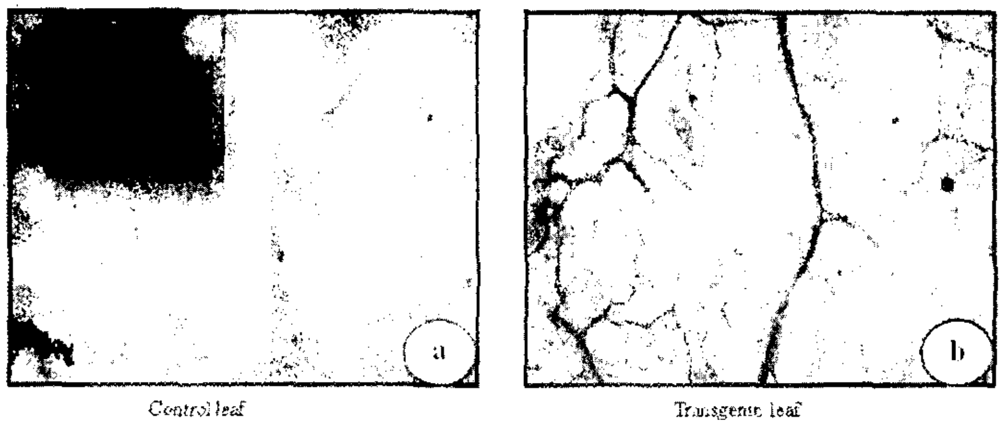

Fig. 1.

Fig 1b shows the GUS expression in the primary leaf 7 days after infection where as endogenous GUS-like activity was seen in the non transformed controls Fig 1a. 7 days after co-cultivation, primary leaf from each seedling were harvested and kept in x-gluc solution and incubated at 37°C for 12-15 hr to analyze the presence of the introduced genes. The tissues were later transferred to 75% ethanol to clear the chlorophyll.

DNA analysis: For isolating genomic DNA and analysis of the plants individually from each batch is a time consuming process hence, they were divided them into groups, each group contains 5 plants. From the positive group, genomic DNA isolated individually and analyzed for presence of transgene. A total number of 956 plants were analyzed by 200 groups. Analysis for *Uid A* gene revealed the presence of a 1.2 kb amplicon in 4 plants of 18 plants tested. No amplification was observed from DNA of untransformed castor plants (Fig. 2).

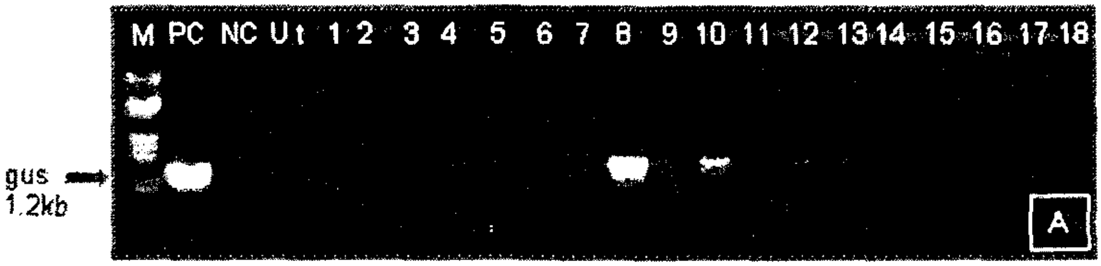

Fig. 2. PCR analysis of primary transformats showing amplification of 1.2 kb fragment of GUS gene.

M: *HindIII+EcoRI* double digest marker, PC: positive control (pCAMBIA 2301 DNA), NC: negative control, Ut: DNA from untransformed control, **1-18: DNA** from primary transformants.

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Efficiency of different methods of transformation in castor, *Ricinus communis* L.

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Abstract

Plant regeneration through tissue culture based methods is a major limitation in castor. Hence, development of transgenics was done through exploitation of the excessive proliferating ability of meristematic explants. Genetic transformation in castor was carried out using both vector- mediated and direct gene transfer methods. For *Agrobacterium*-mediated transformation embryo axis and hypocotyl tissue from zygotic embryo axis explants were used. For direct gene transfer using particle gun bombardment, embryo axis from mature seeds were used as target tissues. There was no significant difference in the frequency of transformation with these methods. In *Agrobacterium*- mediated genetic transformation method, the frequency of recovery of putative transformants after three cycles of selection was 1.18% and 0.78% with embryo axis and hypocotyls explants, respectively. In particle gun bombardment, the frequency of recovery of putative transformants after three cycles of selection was 1.14%. Both the methods are being used to develop transgenic castor harboring insect resistance (*Cry IAa, Cry IEc, Cry IAc*) genes.

Keywords: Castor, meristem-based transformation, genetic transformation, *Agrobacterium tumefaciens*, particle gun bombardment

Introduction

Castor is one of the major oilseed crops of India and in fact, India with an annual production of 11.2 lakh t is the leading producer of castor in the world. The major problem limiting castor production in India is the susceptibility of released varieties and hybrids to a number of foliage feeders of which castor semilooper, *Spodoptera litura* and capsule borer cause economic yield losses. Genetic enhancement of host plant resistance through conventional breeding procedures is constrained by lack of acceptable levels of resistance in the cultivar germplasm. Hence, alternative approaches like alien gene transfer and biotechnological innovations are envisaged for genetic upgradation of this crop. Genetic transformation in the studies carried out so for are based on meristem-based method (Sujatha and Reddy, 1998) which results in very low transformation efficiency (@1%). Furthermore, the genes deployed in the earlier studies were *Cry 1Aa, Cry 1Ec* (Sujatha *et al.*, 2009) and *Cry 1Ab* (Malathi *et al.*, 2006) which have been used independently and for different target pests. Incorporation of these genes requires several generations of crossing and back crossing. Against these limitations, it is desired to develop transformation protocols with improved transformation efficiency and to deploy a single fusion gene that is effective against a wide range of major insect pests on castor.

Materials and methods

Seeds of castor cv. DCS-9 were used in the study. Decoated seeds were surface sterilized with 0.1% mercuric chloride for 12 min and rinsed five times with sterile distill water. The endosperm was cut carefully to expose the embryos. The papery cotyledons were excised and the embryo axes were used for transformation experiments.

Embryo axes were transformed through *Agrobacterium*-mediated and particle gun bombardment methods. The protocol for *Agrobacterium tumefaciens*-mediated transformation was according to Sujatha and Sailaja (2005). Embryo axes from decotyledonated embryos were pre-cultured on medium supplemented with 0.1 mg/l 6-Benzyladenine (BA) for five days in dark. Elongating embryo axes were injured at the swollen meristematic center with a needle and incubated for 10 min in overnight grown *Agrobacterium* suspension (OD at A_{600} nm = 0.2) under agitation and subjected to vacuum infiltration for 30 min. Explants were co-cultivated for 48 h on basal MS medium and transferred to medium supplemented with 0.5

mg/l Thidiazuron (TDZ) for 10-12 days. The explants were subjected to proliferation and selection for three cycles on medium supplemented with 0.5 mg/l BA, 250 mg/l cefotaxime and the appropriate antibiotic.

In the modified protocol of *Agrobacterium*-mediated transformation method hypocotyl tissues from zygotic embryo axis explants were pre-cultured on medium supplemented with 0.22 mg/l TDZ+MES and 4.0 mg/l BA+MES (Ahn *et al.*, 2007) for five days in dark. Elongating embryo axes were injured at the swollen meristematic center with a needle and incubated for 10 min in overnight grown *Agrobacterium* suspension (OD at A_{600} nm = 0.2) under agitation and subjected to vacuum infiltration for 30 min. Explants were co-cultivated for 5 days on basal MS medium and transferred to medium supplemented with 0.22 mg/l TDZ+MES and 4.0 mg/l BA+MES for 20-22 days. The explants were subjected to proliferation and selection for three cycles on medium supplemented with 0.4 mg/l BA+MES with 250 mg/l cefotaxime and the appropriate antibiotic.

Particle gun bombardment was carried out with embryo axes preincubated on 0.5 mg/l TDZ for five days according to Sailaja *et al.* (2008). Bombardments were done with 1.0 µm gold micro carriers at a helium pressure of 1100 psi and a target distance of 6 cm in a PDS He 1000 gene gun (Biorad, Hercules, CA). Explants were pre-plasmolysed for 2 h on osmoticum medium containing equimolar (0.2 M) concentrations of mannitol and sorbitol and subjected to post-osmoticum for 2 h and transferred to shoot proliferation on MS medium containing 0.5 mg/l BA and after 15 days the explants were transferred to selection medium. The cultures were maintained at 26±2°C under a 16/8-h photo period with light provided by cool white fluorescent lamps at an intensity of 30 µmol/ m/s. Regardless of the method of transformation, selection was carried on increasing concentration of hygromycin (20-40-60 mg/l) and kanamycin (50-100-200 mg/l) with constructs harboring *hpt* and *npt* genes, respectively. Following three cycles of selection of two-week duration each, putative transformants were transferred to medium with 0.5 mg/l BA and 0.2 mg/l BA for shoot proliferation and elongation, respectively. Rooting was accomplished on half-strength MS medium with 2.0 mg/l NAA. Rooted shoots were acclimatized in sterile vermiculite for 7 to 10 days under high humidity and were transferred to soil in pots in transgenic greenhouse. The putative transformed plants were analysed by PCR, RT-PCR and Southern analysis.

Results and discussion

In *Agrobacterium* mediated transformation, variables like bacterial strains (LBA4404 and EHA105 harboring p^{CAMBIA} 1304 plasmid), bacterial cell density ($6.7x10^7$, $1x10^8$, $2x10^8$, $4x10^8$, $8x10^8$ cells/ml), bacterial incubation period (10, 20, 30 min), meristematic explants (cotyledone node, embryo axis from mature seed, shoot apices of seedling explants and embryos from mature and immature seeds), MS salt strength during co-cultivation (full, 1/2, 1/4, 1/8), genotypes (48-1, Aruna, VP-1, DCS-9, Bhagya), acetosyringone a phenolic compound which acts as an inducer of *vir* genes (0-200 µM), micro-wounding (glass beads, pricking with hypodermic needle, incision on meristematic zone with blade, particle gun bombardment at 1,100 psi using uncoated microcarriers) were tested. Among all these variables use of 5day-old embryo axes injured at the swollen meristematic center with a needle and incubated for 10 min in overnight grown *Agrobacterium* suspension (OD at A600 nm = 0.2) under agitation and subjected to vacuum infiltration for 30 min showed significantly high *gus* expression (Sujatha and Sailaja 2005). In *Agrobacterium* mediated genetic transformation method, the frequency of recovery of putative transformants after three cycles selections was 1.18%. While it was 0.78 % in the modified protocol of *Agrobacterium*-mediated transformation. Ahn et al (2007) stated that the protocol described by them could give a higher frequency of transformation but our study showed that the transformation frequency from hypocotyls tissues was significantly lower than that for embryo-axis transformation developed in the laboratory.

In particle gun bombardment method, preliminary investigations were carried out with different concentrations of DNA (1, 2, and 5 µg/ml), osmoticum (pre, post, or both pre and post), explant (embryo axes from mature seeds, very young embryos, immature embryos, proliferating shoots from shoot apices, coteledonary nodes and shoot tips), helium pressure (450, 650, 900, 1,100 and 1350 psi), microcarrier type and size (gold 0.6, 1, 1.6 µm, tungsten 1, 1.7 µm), target distance (6, 9 and 12 cm) and number of bombardments (single and double), etc. Use of osmoticum (mannitol and sorbitol) in the bombardment medium increased the frequency of transient and stable transformation. Compared to all particle sizes and helium pressures, 1.0 µm particle size (gold) and 1100 psi with 1 µg/ml DNA concentration showed significantly high *gus* expression, whereas the pressure of 650 psi showed a low response. In particle gun bombardment method, the frequency of recovery of putative transformants after three cycles of selection was 1.14%.

Both *Agrobacterium*-mediated and particle gun bombardment methods are being used to transform castor with constructs harboring insect resistance (*Cry 1Aa, Cry 1Ec, Cry 1Ac*) genes. There is no significant difference among all these methods because transformation involves meristem-based transformation. Transformation of meristematic tissues is refrected to produse chemaras and hence, attempts are underway to optimize tissue culture protocols for whole plant regeneration in castor.

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Assessment of genetic diversity in castor (*Ricinus communis* L.) using RAPD and ISSR markers

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Abstract

The present investigation has been undertaken to assess the extent of genetic diversity in a representative set of 31 accessions of *Ricinus communis* L. from 6 geographic origins in the world. Out of 214 RAPD primers tested, 145 primers produced amplification products of which 125 revealed polymorphic fingerprint patterns. Out of a total 797 bands, 438 (54%) were polymorphic with an average of 3.5 polymorphic bands/primer. The total number of bands/amplification varied from 1-12 in the molecular size range of 200-3,100 bp. Out of 100 ISSR primers tested, 42 primers produced amplification products of which 25 revealed polymorphic fingerprint patterns. Out of a total 227 ISSR bands, 88 (38%) were polymorphic with an average of 3.5 polymorphic bands/primer. The total number of bands/amplification varied from 1-15 in the molecular size range of 200-3,100 bp. The present investigation indicates a modest level of genetic variation in the *Ricinus communis* L. accessions as revealed by RAPD and ISSR marker technique. The 31 accessions were classified into four clusters, cluster I included 4 accessions, cluster II was a major cluster comprising 20 accessions, cluster III includes only one accession and cluster IV includes 6 accessions.

Keywords: Castor, genetic diversity, RAPD, ISSR

Introduction

Castor (*Ricinus communis* L., 2n=2x=20, Euphorbiaceae), is an industrially important non-edible oilseed crop widely cultivated in the arid and semi-arid and well adapted to the temperate regions of the world (Govaerts *et al.*, 2000). The seeds of castor contain more than 45% oil which is rich (80-90%) in an unusual hydroxyl fatty acid, ricinoleic acid (Jeong and Park, 2009). Owing to its unique chemical and physical properties, the oil from castor seed is used as raw material for varied industrial applications, such as manufacture of polymers, surface coatings, lubricants for air crafts, cosmetics, etc., and production of biodiesel (Jeong and Park, 2009). The world production of castor seed hovers around an average of 15.8 lakh t. The major castor producing countries are India, China, Brazil, Paraguay, Ethiopia, Philippines, Russia and Thailand. India accounts around 70% of the share in production with a production value of 11.2 lakh t (FAOSTAT, 2008).

Germplasm collections constitute one of the world's most readily available sources of plant genetic material (Allard *et al.*, 1991). Managers of these collections strive to accumulate and maintain these collections as a way of preserving the biological diversity of crops and other economically important plant species (Gilbert *et al.*, 1999). An understanding of the extent of genetic diversity is critical for the success of a breeding programme. Traditional methods using morphological characteristics for establishment of genetic diversity and relationships among accessions are largely unsuccessful due to the strong influence of environment. Hence, selection based on genetic information using neutral molecular markers is essential, as it is more reliable and consistent. In Euphorbiaceae, molecular markers such as RAPD, RFLP, AFLP, and SSRs have been employed for determining the extent of genetic diversity in elite rubber (Hevea brasiliensis) clones (Besse *et al.*, 1994; Varghese *et al.*, 1997; Lakawipat *et al.*, 2003), cassava (Asante and Offei 2003; Fregene *et al.*, 2003), *Jatropha* (Basha and Sujatha 2007), present investigation, we examined the genetic diversity among the castor germplasm from different geographic origins. To examine the genetic diversity of castor bean germplasm we employed two marker methods viz RAPD and ISSR were employed.

Materials and methods

We selected 31 accessions of *Ricinus communis* L. representing germplasm distribution of castor from seven countries (USA, Nigeria, Kenya, Egypt, Brazil, USSR and India) (Table 1). The seeds of 31 accessions were grown at the research farm of the Directorate of Oilseeds Research, Hyderabad, India.

Accession Number	Country/Origin/Source
RG-102	United States of America
RG-2443	United States of America
RG-2444	United States of America
RG-2451	United States of America
RG-2452	United States of America
RG-2674	United States of America
RG-2677	United States of America
RG-798	Nigeria
RG-799	Nigeria
RG-801	Nigeria
RG-802	Nigeria
RG-1155	Nigeria
RG-1163	Nigeria
RG-1164	Nigeria
RG-1171	Nigeria
RG-1172	Nigeria
RG-1174	Nigeria
RG-1581	Kenya
RG-1582	Kenya
RG-761	Egypt
RG-792	Egypt
RG-100	Brazil
RG-117	USSR
VP-1	India
M-574	India
DPC-9	India
DPC-11	India
DPC-15	India
DCS-9	India
48-1	India
Kranthi	India

DNA extraction

The total genomic DNA was extracted from younger leaves of ten plants for each of the castor accessions following the standard CTAB method with minor modifications (Doyle and Doyle 1990). Five grams of leaves were ground in liquid nitrogen, then homogenized in 20 ml of extraction buffer (2% CTAB, 20 mM EDTA, 2% PVP, 1.4 M NaCl, 100 mM Tris-HCl pH 8.0 and 1% β-mercaptoethanol) and incubated at 65°C for 1 h. The supernatant was twice extracted with chloroform:isoamylalcohol (24: 1 v/v), treated with RNase A (100 μg/ml) and incubated at 37°C for 30 min. The pelleted DNA was air dried and resuspended in 500 μl of sterile MilliQ water and stored at -20°C. The DNA concentration was determined electrophoretically using known amount of λ DNA as standard.

RAPD analysis

The PCR amplification reaction (10 μl) consisted of 2.5 ng of DNA, 1x PCR buffer (10 mM Tris pH 9.0, 50 mM KCl, and 1.5 mM $MgCl_2$), 100 μM of each of the four dNTPs, 0.4 μM of RAPD primer and 0.3 U of *Taq* DNA polymerase (Bangalore Genei, India). PCR amplifications were performed in a GeneAmp 9700 Thermal Cycler (PerkinElmer Applied Biosystems) with an initial denaturation at 94°C for 3 min followed by 45 cycles at 94°C for 45 s, 36°C for 30 s and 72°C for 2 min with a final extension at 72°C for 7 min. The PCR products were separated on 1.5% agarose gel in 1x TAE buffer by electrophoresis at 100 V for 3 h and visualized with ethidium bromide staining. All the PCR amplifications included a negative control (no DNA) to avoid erroneous interpretation.

ISSR-PCR amplification

The PCR amplification reaction (10 µl) consisted of 2.5 ng of DNA, 1x PCR buffer (10 mM Tris pH 9.0, 50 mM KCl, and 1.5 mM $MgCl_2$), 200 µM of each of the four dNTPs,0.2 µl of 25 mM $MgCl_2$, 0.4 µM of ISSR primer and 0.6 U of Taq DNA polymerase (Bangalore Genei, India). PCR amplifications were performed in a GeneAmp 9700 Thermal Cycler (PerkinElmer Applied Biosystems) with an initial denaturation at 94°C for 4 min followed by 35 cycles at 92°C for 30s, 1 min at the annealing temperature (36-60°C depending on the primer) and 72°C for 2 min with a final extension at 72°C for 7 min. The PCR products were separated on 1.7% agarose gel in 1x TAE buffer by electrophoresis at 100 V for 3 h and visualized with *ethidium bromide staining. All the PCR amplifications included a negative control (no DNA) to avoid erroneous interpretation.*

The gel images were recorded using the Alpha Innotech Fluorchem gel documentation system. For each RAPD and ISSR primer, the presence or absence of bands in each accession was visually scored and set in a binary matrix. The number of polymorphic and monomorphic fragments for each primer pair was scored and the monomorphic markers were excluded from the analysis. The binary matrices were read by NTSYS-pc version 2.02i with Jaccard's similarity coefficients and *estimates of genetic distances for all pair wise comparisons between accessions were determined using Similarity for* Qualitative Data (SIMQUAL). Dendrograms based on UPGMA (Unweighted Pair Group Method with Arithmetic Mean) were constructed for the both marker systems.

Results and discussion

RAPD: Out of 214 RAPD primers tested, 145 primers produced amplification products of which 125 revealed polymorphic fingerprint patterns. Out of a total 797 bands, 438 (54%) were polymorphic with an average of 3.5 polymorphic bands per primer. The total number of bands per amplification varied from 1-12 in the molecular size range of 200-3,100 bp (Fig. 1). *Similarity matrix values using Jaccard's coefficient ranged from 0.70 to 0.95. The highest value similarity coefficient (0.90)* was detected between accessions 18 and 19 from Kenya.

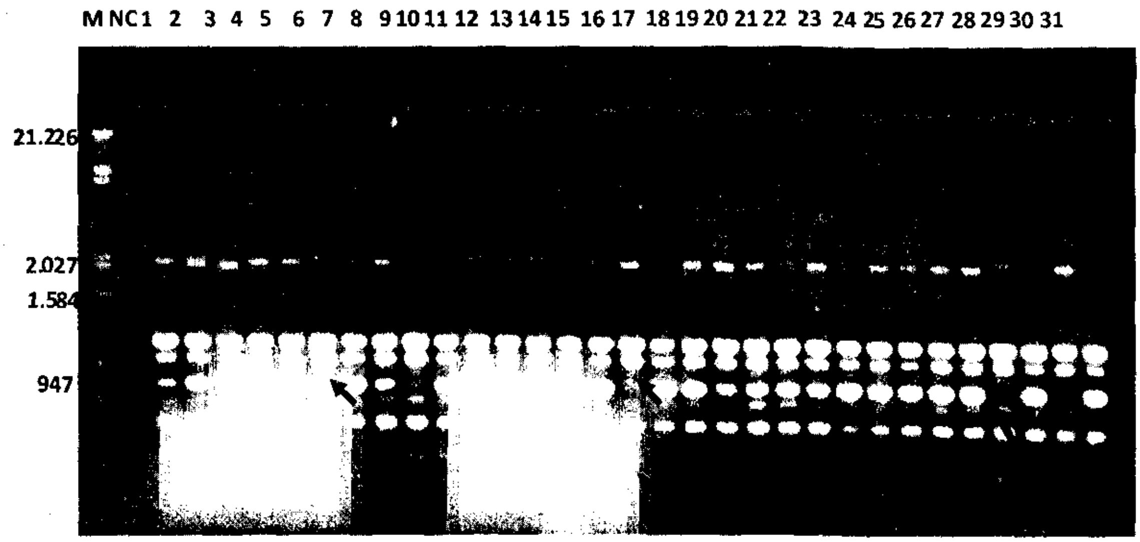

Fig. 1 Electrophoretic analysis of DNA amplification produced using RAPD primer OPO 18. Lanes designated as M represents λ DNA double digest with *EcoRI* and *HindIII* restriction enzymes, Nc-negative (no DNA) control, and 1-31 the samples used in the study

ISSR: Out of 100 ISSR primers tested, 42 primers produced amplification products of which 25 revealed polymorphic fingerprint patterns. Out of a total 227 bands, 88 (38%) were polymorphic with an average of 3.5 polymorphic bands per primer. The total number of bands per amplification varied from 1-15 in the molecular size range of 200-3,100 bp (Fig. 2). Similarity matrix values using Jaccard's coefficient ranged from 0.70 to 0.96. The highest similarity coefficient value (0.95) was detected between accessions 18 and 19 from Kenya.

The RAPD and ISSR data were combined for UPGMA cluster analysis. The clustering pattern of the genotypes was almost similar with both the marker systems and most of the accessions were placed in their respective clusters (Fig. 3). The 31 accessions were classified into four clusters, cluster I included 4 accessions from USA (3), Nigeria (1). Cluster II was a major cluster and included 20 accessions from USA (4), Nigeria (8), Kenya (2), Egypt (2), India (3) and Brazil (1). Cluster III included only one accession from Kenya. Cluster IV included 6 accessions from India.

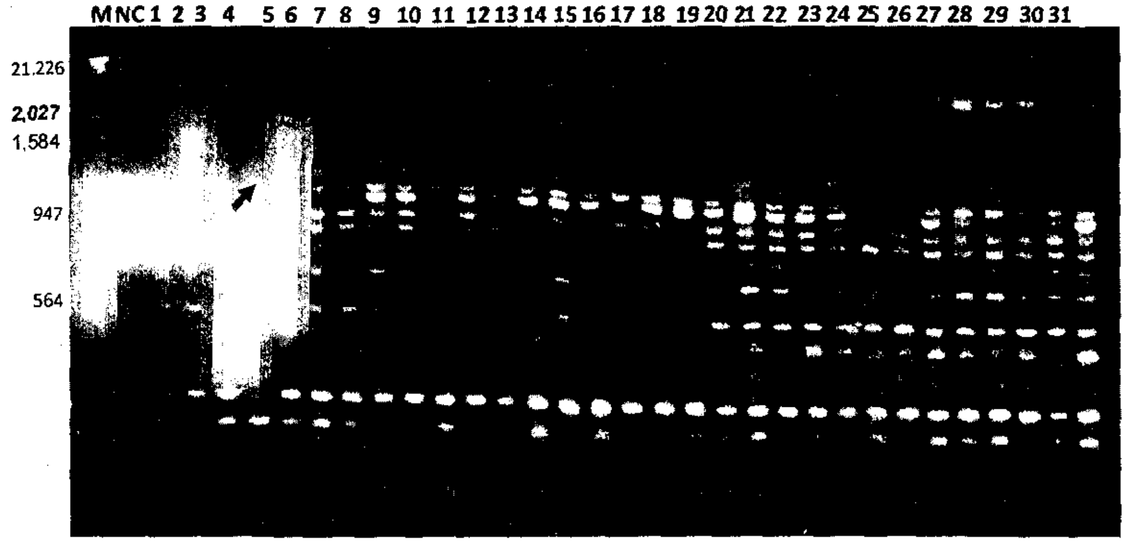

Fig. 2 Electrophoretic analysis of DNA amplification produced using ISSR primer UBC-834. Lanes designated as M represents λ DNA double digest with *EcoRI* and *HindIII* restriction enzymes, Nc-negative (no DNA) control, and 1-31 represent the samples used in the study

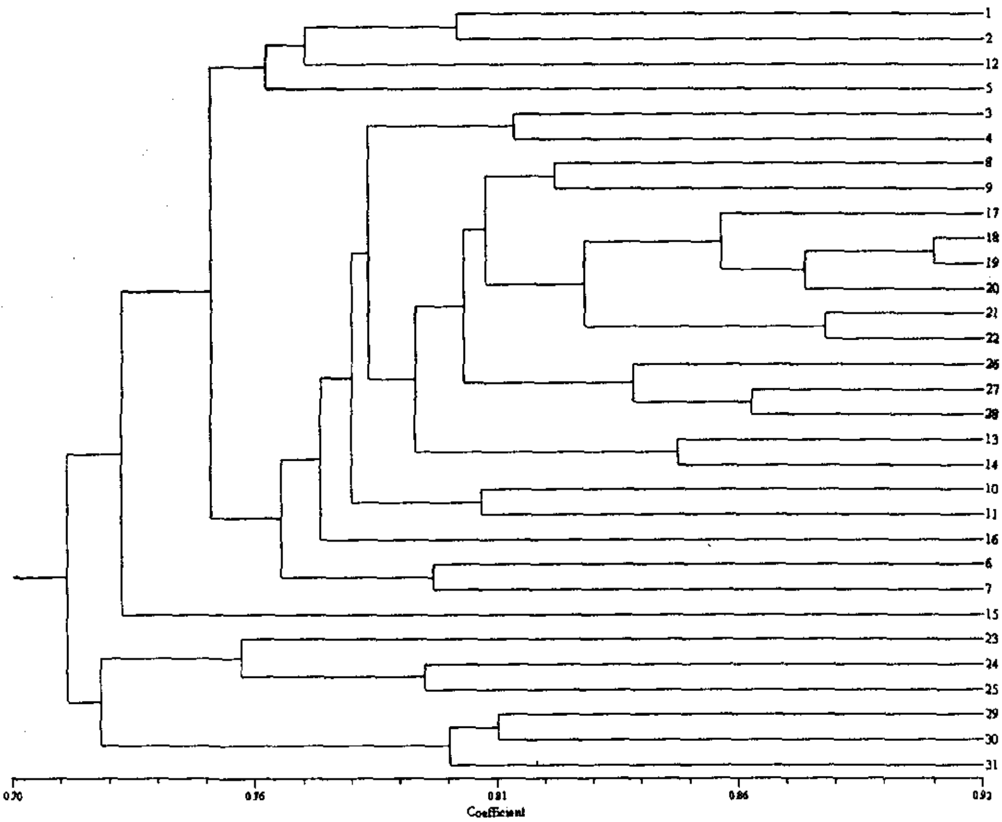

Fig. 3 UPGMA dendrogram representing genetic relationships among 31 accessions of *Ricinus communis* L based on genetic similarity matrix obtained using the pooled allelic profile of RAPD + ISSR primers

Numerous PCR-based markers are employed for characterization of genetic diversity in plants for both wild and cultivated populations. In the present study, 214 RAPD and 100 ISSR primers produced 526 polymorphic bands that discriminated the 31 castor genotypes into four clusters. RAPD markers exhibited a high level of polymorphism (54%) compared to ISSR markers (38%).

UPGMA- dendrogram of both RAPD and ISSR displayed similar grouping of accessions with minor deviations. UPGMA-dendrogram of RAPD + ISSR classified the total accessions into four main clusters. Cluster II is the major cluster with 20 accessions in it. Accessions 18 and 19 from Kenya) showed the highest value of similarity coefficient with both RAPD and ISSR markers. These studies indicate a modest level of genetic variation in the castor accessions despite the geographic distance.

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Variability, heritability and genetic advance in castor, *Ricinus communis* L.

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Abstract

Genetic variability and heritability of different characters were studied using 70 genotypes including two standard checks. The genotypes showed wide range of variation for all the characters. High coefficient of variation was observed for plant height, spike length and effective spikes/plant. High values of heritability coupled with high genetic advance as % of mean was observed for days to 50% flowering, plant height and primary spike length.

Keywords: Variability, heritability, PCV, GCV, genetic advance

Introduction

The seed yield being complex character, governed by mutiple genes and highly influenced by environment and a thorough knowledge of variability owing to genetic factors i.e., actual genetic variation heritable on the progeny and the genetic advance that can be achieved through selection is essential. Moreover, heritability estimate along with genetic advance is more useful than the heritability estimate alone in predicting resultant effect for selection of the best individual from segregating population. Therefore, the present investigation aimed at to assess the variability, heritability and genetic advance of seed yield and other quantitative characters to select superior genotypes.

Materials and methods

The experimental material consisted of 70 castor genotypes including, two standard checks *viz.*, Kranthi and Haritha, were grown in a randomized block design, replicated thrice with a spacing of 90 cm x 60 cm during the winter season of 2009 at the Regional Agricultural Research Station, Palem. Five plants were randomly selected from each entry/replication and observations were recorded for days to 50% flowering, plant height, number of nodes upto primary spike, primary spike length, effective spikes/plant, 100 seed weight and seed yield/plant. The phenotypic and genotypic variance, phenotypic and genotypic coefficient of variation, heritability and genetic advance as % of mean were calculated following standard methods. The estimates of PCV and GCV were classified as low (less than 10%), medium (10-20%) and high (greater than 20%) (Sivasubramanian and Madhavamenon, 1973). Heritability estimates (broad sense) for yield components of sunflower genotypes were worked out following Singh and Chaudhary (1985). The heritability estimates were categorized as suggested by Robinson *et al.* (1949) (0-30% = low; 31-60% = moderate; above 60% = high). Genetic advance was estimated by adopting the method given by Johnson et al. (1955) (more than 20% = high; 10-20% = moderate; less than 10% = low).

Results and discussion

The analysis of variance revealed significant genotypic differences for all the seven characters studied. The range of variation was maximum for plant height (35.6-117.1 cm), followed by primary spike length (17.1 to 67.2 cm) and yield/plant (53.0 to 109.7 g) (Table 1). The higher mean was associated with high range, indicating the scope of improvement through simple selection procedure.

Variances and coefficient of variation (Table 1) indicated that there were little or no differences between phenotypic and genotypic variance for some of the characters *viz.*, days to 50% flowering indicating that these characters were less affected by environment. On the other hand characters such as number of nodes upto primary spike, primary spike length, effective spikes/plant, 100 seed weight and seed yield/plant were the most affected by the environment.

For meaningful comparison among characters for variability, standardization with respective mean values was done to get PCVs and GCVs. It is clear that using coefficients of variation as a measure, the magnitude of variation was maximum for plant height followed by effective spikes/plant, primary spike length and yield/plant. Low variability was observed for 100 seed weight, number of nodes upto primary spike and days to 50% flowering. The results are generally in agreement with the reports of Patel and Jaimani (1988), Lakshmamma *et al.* (2005) and Golakia *et al.* (2007).

High heritability (broad sense) estimates were observed for days to 50% flowering, plant height and primary spike length indicated that the dependence of phenotypic expression reflect the genotypic ability to transmit the genes to their off spring. Johnson *et al.* (1955) further suggested that high heritability considered together with high genetic advance is more reliable in predicting desirable improvement for plant height and primary spike length. It further showed that these characters are amenable for improvement by selection, particularly by mass selection (Krishnawat and Sharma, 1998). Such values of high heritability and genetic gain may be attributed to additive effect (Panse, 1957). Hence, selection in segregating generations would be very effective for these characters.

Table 1 Variability parameters for seed yield and its component characters in castor

Character	Range			Variance		Coefficient of variation		Heritability (%)	Genetic as % mean
	Minimum	Maximum	Mean	Phenotypic	Genotypic	Phenotypic	Genotypic		
Days to 50% flowering	43.3	65	53.6	33.987	23.18	10.87	8.97	68.2	15.2
Plant height (cm)	35.6	117.1	67.1	454.54	433.00	31.75	30.99	95.3	62.3
No. of nodes upto primary spike	10.5	19.0	14.7	4.12	1.28	13.79	7.69	31.1	8.8
Primary spike length (cm)	17.1	67.1	39.8	133.44	81.66	29.01	22.69	61.2	36.5
Number of effective spikes/plant	4.666	11.7	7.7	5.73	2.36	31.00	19.92	41.3	26.3
100 seed weight (g)	21.0	30.6	25.8	6.93	2.85	10.20	6.55	41.2	8.6
Seed yield/plant	53.0	109.6	77.0	199.29	113.76	18.33	13.85	57.1	21.5

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Molecular tagging of *Fusarium* wilt resistance gene(s) in castor, *Ricinus communis* L.

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Abstract

Inheritance studies on *Fusarium* wilt resistance and molecular tagging of the resistance gene(s) was taken up. Based on screening results in wilt sick plot, Kranthi was used as susceptible parent and Haritha and Jwala as resistant parents and mapping populations (F_2 and BC_1) were developed. Inheritance studies revealed resistance to be dominant over susceptibility and is governed by single dominant gene in Haritha and Jwala. Parental polymorphism was studied using 160 operon primers. Of the 330 repeatable amplified fragments produced by these 160 primers, 56 primers (16.96%) showed polymorphism between the parents between Kranthi and Haritha and 48 primers (14.54%) showed polymorphism between Kranthi and Jwala. In bulked segregant analysis, 2 primers i.e. H12, J15, were polymorphic between resistant and susceptible bulks in the cross (Kranthi x Haritha) and 1 primer i.e., J15 was polymorphic in cross (Kranthi x Jwala). Screening of mapping populations revealed that the markers H12 and J15 were closely linked to *Fusarium* wilt resistant genes in castor.

Keywords: Castor, *Fusarium* wilt, genetic resistance, molecular mapping

Introduction

Castor (*Ricinus communis* L.) plays an important role in the country's vegetable oil economy. Castor is an important non-edible oilseed crop of Andhra Pradesh, mainly grown in Mahaboobnagar, Nalgonda, Ranga Reddy, Kurnool, Kadapa nd Prakasam Districts. The productivity of the crop in the state is 511 kg/ha, which is far below the national average of 1339 kg/ha. The major reason for the dismal state of production in the state is erratic rainfall and poor management practices. Apart from these biotic and abiotic stresses constitute the major yield destabilizing factors to realize the full potential of the currently available varieties. *Fusarium* wilt and *Botrytis* grey rot contribute significantly to yield losses. Though wilt resistant varieties were developed for cultivation, breakdown of resistance has become a serious concern. Further, it was observed the existence of more than one race, which is common for soil borne pathogens. Molecular marker technology, among its variety of applications, enables precision in selection/screening at genotype level and in unfolding the hitherto hidden variability of breeding value. In this context, it was attempted to study the genetics of *Fusarium* wilt resistance (FWR) and to tag the gene(s) governing the *Fusarium* wilt resistance. The identified markers will be used in marker-assisted selection (MAS) for gene pyramiding to develop durable resistant varieties.

Materials and methods

The experimental material consisted of 35 germplasm lines and three released varieties *viz.*, Kranthi, Haritha and Jwala. A wilt sick plot developed at RARS, Palem with the *Fusarium* culture was used for screening of the genotypes. During the rainy season of 2007, the test material was sown in the sick plot and the susceptible variety was sown all along the circumference of the plot. Each entry was sown in a single row of 6m length. Susceptible check, Kranthi (85-100 % wilt) and resistant check, Haritha were included after every five test rows. Nematode population was controlled by soil application of carbofuron (1 kg a.i./ha) before sowing and normal management practices were taken for the control of other diseases and insect pests. Observations were recorded for % wilt incidence on susceptible plants from the first appearance of the wilt at an interval of 30 days upto crop maturity (150 days). The resistance of the test material was confirmed only when the test material is free from wilting, while the susceptible variety showed wilting symptoms and died subsequently. The plants die at different stages of crop duration upto 150 days were classified as a susceptible.

Per cent of disease incidence (PDI) was calculated by using the formula

$$PDI = \frac{\text{Number of plants infected}}{\text{Total number of plants in each genotype}} \times 100$$

On the basis of the disease reaction (PDI), the genotypes were grouped into the following categories:

Resistant	:	less than 20% wilt incidence
Moderately resistant	:	20 -50% wilt incidence
Susceptible	:	more than 50 % wilt incidence

Based on the disease reaction, Kranthi was used as susceptible parent and Haritha and Jwala were used as resistant parents for hybridization. The mapping population for tagging the gene(s) conferring resistance to the disease was developed using two crosses *viz.*, Kranthi x Haritha and Kranthi x Jwala. Crosses were effected at the RARS, Palem during the winter season of 2007. During the rainy season of 2008, the F_1s were selfed to produce F_2. Also, F_1 plants was used as male parent and susceptible recurrent parent (Kranthi) were used as female parent to produce backcross population. At the time of harvest, the seed from each BC_1 plant was harvested separately and stored for future use. During winter season of 2008, all the five populations *viz.*, P_1, P_2, F_1, F_2, B_1 (backcross with Kranthi) of both the crosses (Kranthi x Haritha) and (Kranthi x Jwala) were screened for *Fusarium* wilt in wilt sick plot. To study the genetic basis of resistance to wilt, 500 F_2 plants from each cross were screened for reaction to wilt disease. Also 200 plants in BC_1 were screened to confirm the results obtained in F_2 screening. The data was analyzed using chi-square test. For tagging of *Fusarium* wilt resistance gene(s) 100 F_2 and BC_1 individual plants of both crosses were utilized. The genomic DNA was isolated from the parents (Kranthi, Haritha and Jwala), F_1, F_2s (Kranthi x Haritha), and (Kranthi x Jwala) and back cross populations [Kranthi x (Kranthi x Haritha)] and [Kranthi x (Kranthi x Jwala)]. The Genomic DNA was isolated from the fresh leaves collected from the field by using CTAB method (Doyle and Doyle, 1987), with a few modifications. The DNA quantification was done by using a spectrophotometer. PCR analysis was carried out following the technique developed by Williams *et al.*,1990), with slight modifications. The primers used in this study obtained from Operon Technologies Inc., Almeda, California. A single primer was used for each PCR amplification reaction (Welsh and Mc Clelland, 1990).

To study parental polymorphism a set of 160 operon RAPD primers were screened between the parents, Kranthi, Haritha and Jwala. Following parental polymorphism using appropriate RAPD primers, closely linked markers to resistance will be identified by bulked segregant analysis (BSA) (Giovannoni *et al.*, 1991; Milchemore *et al.*, 1991). The essence of this procedure is creation of a bulk sample of DNA for analysis by pooling DNA from individuals with similar phenotypes (resistant/susceptible). One bulk containing DNA from five plants that were resistant to wilt and the second bulk containing DNA from five plants that were susceptible to wilt. In the analysis the resistant and susceptible bulks were made from F_2 and B_1 generations. The markers identified to be polymorphic between parents were used to screen in the bulked segregant analysis. The markers which showed clear polymorphism between parents and bulks were identified. Those markers were used in screening of mapping population.

Results and discussion

Inheritance to *Fusarium* wilt resistance was studied in two crosses *viz.*, Kranthi x Haritha and Kranthi x Jwala. The F_1 in both the crosses (Kranthi x Haritha) and (Kranthi x Jwala) were resistant to the disease. F_2 segregating population from the crosses (Kranthi x Haritha) and (Kranthi x Jwala) were studied to understand genetics. A segregation of 3:1 (resistant: susceptible) was observed in F_2 generation in both the crosses (Table 1). Both the backcrosses (Kranthi x (Kranthi x Haritha) and [Kranthi x (Kranthi x Jwala)] gave a segregation ratio of 1 resistant: 1 susceptible plants. From the results it can be concluded that resistance was dominant over susceptibility due to its expression in F_1 and the genetic nature of the disease resistance was governed by a single dominant gene. The results were confirmed with backcross segregation ratios. The results were in confirmation with Desai *et al.* (2001).

For tagging molecular markers linked to *Fusarium* wilt resistance gene(s), parental polymorphism was studied using a set of 160 operon RAPD primers were screened between the parents, Kranthi, Haritha and Jwala. Of the 330 repeatable amplified fragments produced by these 160 primers, 56 primers (16.96%) showed polymorphism between the parents between Kranthi and Haritha (Fig. 1) and 48 primers (14.54%) showed polymorphism between Kranthi and Jwala. The scoring of the population was done on the basis of the presence of band (1) and absence of the band (0) and given code as A or B respectively. The markers identified to be polymorphic between parents were used to screen in the bulked segregant analysis. In the cross Kranthi x Haritha, two primers (OPH12 and OPJ15) (Fig. 2) and in cross Kranthi x Jwala, one primer (OPJ15) showed clear polymorphism between parents and bulks. These identified primers were used in screening of mapping population.

Table 1 Mode of inheritance of *Fusarium* wilt resistance in various segregating generations of castor in two crosses (Kranthi x Haritha and Kranthi x Jwala)

Generation	Total plants	Observed frequencies		Expected frequencies		Ratio R:S	χ^2
		Resistant (R)	Susceptible (S)	Resistant (R)	Susceptible (S)		
				Kranthi × Haritha			
P_1	42	9	33	-	-	-	-
P_2	44	41	3	-	-	-	-
F_1	43	39	4	-	-	-	-
F_2	500	387	113	375	125	3:1	1.55
BC_1	200	116	94	100	100	1:1	0.08
				Kranthi × Jwala			
P_1	46	9	37	-	-	-	-
P_2	47	44	3	-	-	-	-
F_1	46	7	39	-	-	-	-
F_2	500	371	129	375	125	3:1	0.128
BC_1	200	108	92	100	100	1:1	0.32

Screening the mapping population of the cross Kranthi x Haritha with OPH12 primer revealed that 100 F_2 individual plants gave a segregation of 64 resistant and 36 susceptible plants (Fig. 3). The F_2 ratio confirms with the expected ratio 3:1(resistant: susceptible). Further, the back cross of 100 plants segregated with a good fit to 1 resistant: 1 susceptible plants. Like wise, screening the mapping population with of the cross Kranthi x Jwala with J15 primer indicated that 100 F_2 individuals of segregated in the ratio of 68 resistant to 32 susceptible plants. The F_2 ratio confirms with the expected ratio 3:1(resistant: susceptible). Further, the backs cross of 100 plants segregated with a good fit to 1 resistant: 1 susceptible plants. It can be concluded that the marker H12 and J15 were closely linked to *Fusarium* wilt resistant genes in castor. The amplicon size amplified by both the primers was close to 1584 bp by which it can be concluded that binding site for both these primers was possibly same.

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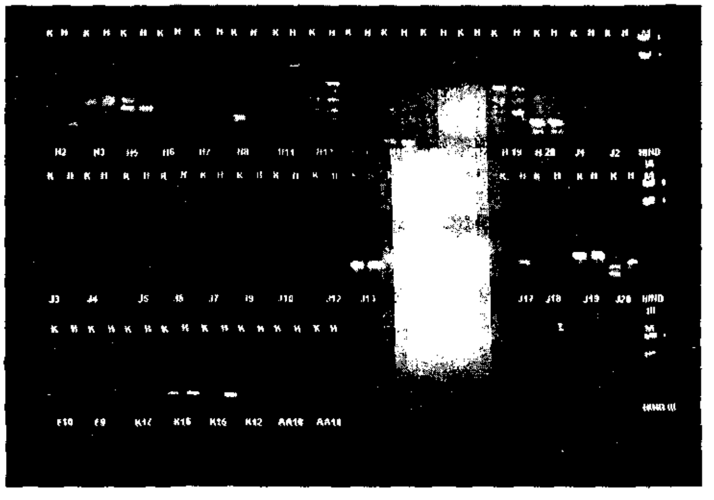
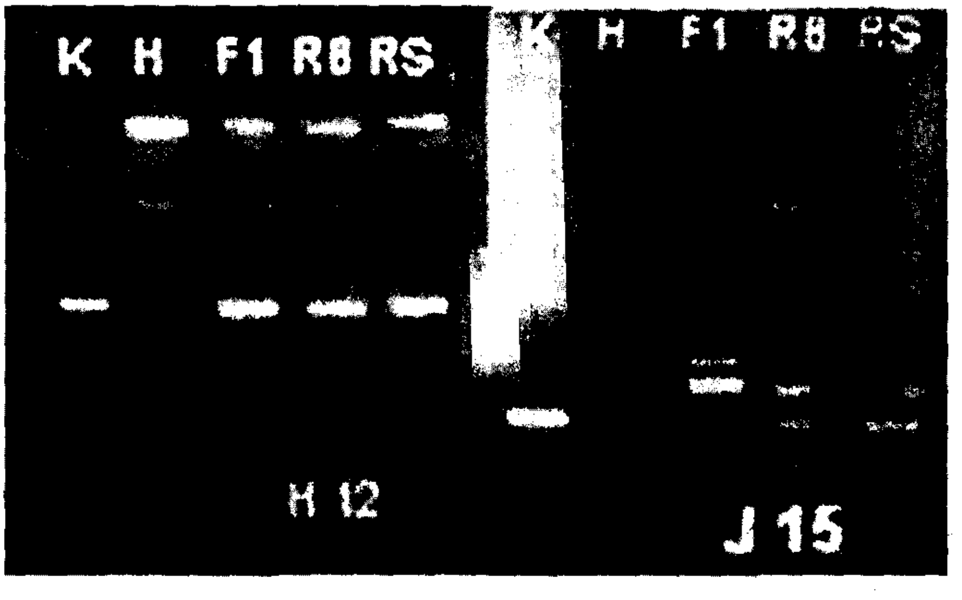


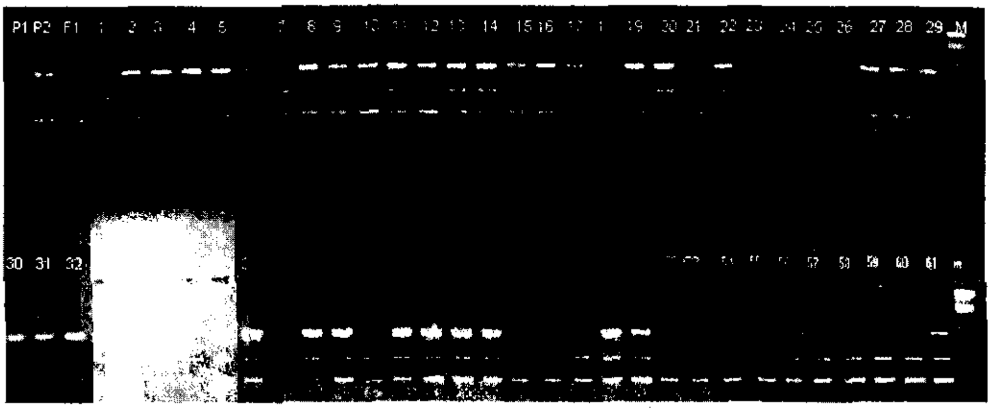
K = Kranthi and H = Haritha

Fig. 1. Parental polymorphism studies in Kranthi and Haritha



K = Kranthi; H = Haritha; RB = Resistant bulk; RS = Susceptible bulk

Fig. 2. Bulked segregant analysis in cross Kranthi x Haritha using OPH12 and OPJ 15



P1 = Kranthi; P2 = Haritha; M = 100 bp + 1.5 kbp DNA latter

Fig. 3. Screening of mapping population (F_2) in cross Kranthi x Haritha using OPH 12

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Heterosis studies in castor, *Ricinus communis* L.

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Abstract

Seven elite lines consisting of released varieties (Haritha, Kranthi, Kiran), advanced breeding lines (PCS-170, PCS-171) and pistillate lines (VP-1 and DPC-9) were crossed in diallel method excluding reciprocals. The resultant 21 hybrids were evaluated along with their parents and a standard check, GCH-4 in a randomized block design, replicated thrice. Observations were recorded on days to 50% flowering, plant height, number of nodes up to primary spike, primary spike length, number of effective spikes/plant, 100 seed weight and seed yield/plant. Data obtained was subjected to heterosis analysis to estimate heterosis, heterobeltiosis and standard heterosis. From the present investigation four hybrids *viz*., Haritha x DPC-9, Haritha x VP-1, Haritha x Kranthi and Haritha x Kiran were identified as promising for seed yield and most of the desirable characters.

Keywords: Heterosis, castor, hybrids

Introduction

Castor (*Ricinus communis* L.) plays an important role in the country's vegetable oil economy. The crop is grown for its non-edible oil (45-50% oil in seeds) which is completely biodegradable with its utilization in several fields such as manufacturing lubricants, printing inks, nylon fibers, hydraulic fluids, cosmetics, varnishes, pharmaceuticals and similar others. Castor cake is considered to be excellent organic manure. Eri-silk culture is an emerging field wherein the castor leaves are fed to eri-silk worms. Besides meeting the domestic requirements towards its use in various fields and a variety of diversified products the country is presently dominating international castor oil market. In the present investigation efforts were made to know the nature and magnitude of heterosis in the form of average heterosis, heterobeltiosis and standard heterosis for seed yield and its components.

Materials and methods

The experimental material consisted of seven elite lines including released varieties (Haritha, Kranthi, Kiran), advanced breeding lines (PCS-170, PCS-171) and pistillate lines (VP-1 and DPC-9). These lines were crossed in a diallel method excluding reciprocals during the winter season of 2008 at Regional Agricultural Research Station, Palem. The resultant 21 hybrids were evaluated along with their parents and a standard check, GCH-4 in a randomized block design, replicated thrice at Regional Agricultural Research Station, Palem during the rainy season of 2009.

Each entry was sown in two rows with a row length of 6 m with a spacing of 90 cm x 60 cm. Five plants were randomly selected from each entry and replication and observations were recorded on plant height, number of nodes up to primary spike, primary spike length, number of effective spikes/plant, 100 seed weight and seed yield/plant. Days to 50% flowering was recorded on plot basis. Standard package of practices were followed for growing the crop. Data obtained was subjected to analysis to estimate heterosis, heterobeltiosis and standard heterosis.

Results and discussion

The analysis for variance revealed significant differences for all the characters indicating wide diversity in the material studied. Out of 21 hybrids studied, certain hybrids had significant heterosis over their mid parental, better parent and standard check values.

For days to 50% flowering, plant height, number of nodes up to primary spike and primary spike length, ten, one, three and one hybrid, respectively recorded significantly superior standard heterosis (Table 1 and 2). For number of effective spikes/plant four hybrids registered significant positive standard heterosis. Two crosses Kranthi x PCS-170 and Kiran x VP-1 recorded significant positive standard heterosis for 100 seed weight (Table 2). Similar results were reported by Lavanya *et al.* (2006), Golakia *et al.* (2008) and Patel *et al.* (2009)

The experimental results indicated that for seed yield/plant heterosis to an extent of 26.2 and 26.8% in desirable direction over better parent and standard check GCH-4, respectively, were recorded. Heterosis for seed yield was generally accompanied by heterosis for yield components. From the present investigation Haritha x DPC-9, Haritha x VP-1, Haritha x Kranthi and Haritha x Kiran were identified as promising for seed yield and most of the desirable characters, which could be considered for exploitation of hybrid vigour in castor (Table 2).

In the two crosses *viz.*, Haritha x DPC-9, Haritha x VP-1, one parent is the male line and other one is the pistillate line. Hence, these hybrids should be further evaluated before commercial use. Other two hybrids *viz.*, Haritha x Kranthi and Haritha x Kiran, both the parents are high yielding male lines. From these hybrids superior segregants are expected in further generations.

Table 1 Heterosis, heterobeltiosis and standard heterosis for days to 50% flowering, plant height and number of nodes upto primary spike in castor

Cross	Days to 50 % flowering			Plant height			No. of nodes up to primary spike		
	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check
Haritha X Kranthi	7.95**	7.24*	10.14*	-11.55	-13.28	0.98	5.78	5.78	8.18
Haritha X Kiran	2.89	-0.62	8.11*	1.72	-11.59	-1.07	8.13	6.96	11.82*
Haritha X PCS-170	-6.1	-13.48	4.05	-28.01	-33.4	-25.48	-4.26	-8.16	2.27
Haritha X PCS-171	3.05	1.33	2.7	24.72**	-2.64	8.94	13.88**	7.56	10
Haritha X VP-1	11.81**	7.33*	8.78*	-3.85	-28.17	-19.62	3.93	0.00	2.27
Haritha X DPC-9	-6.67	-10.91	-0.68	-6.02	-12.39	-1.97	2.22	2.22	4.55
Kranthi x Kiran	10.54**	7.45*	16.89**	-12.01	-24.8	-12.43	-2.42	-3.48	0.91
Kranthi x PCS-170	3.03	-4.49	14.86**	-33.62	-39.69	-29.77	-0.85	-4.90	5.91
Kranthi x PCS-171	-7.07	-9.21	-6.76	-0.3	-23.26	-10.64	-2.12	-7.56	-5.45
Kranthi x VP-1	-0.69	-5.26	-2.7	16.29**	-14.24	-0.13	3.46	-0.44	1.82
Kranthi x DPC-9	-5.36	-9.09	1.35	4.97	-3.92	11.89*	-17.78	-17.78	-15.91
Kiran x PCS-170	0.29	-4.49	14.86**	-38.23	-42.29	-45.11	-12.21	-14.9	-5.23
Kiran x PCS-171	13.73**	8.07*	17.57**	-13.37	-23.76	-37.01	32.09	23.48**	29.09**
Kiran x VP-1	-1.00	-8.07	0.00	9.43	-8.66	-24.54	-14.16	-18.26	-14.55
Kiran x DPC-9	9.82**	8.48**	20.95**	-7.58	-14.33	-17.12	-10.33	-11.3	-7.27
PCS-170 x PCS-171	-13.93	-21.91	-6.08	-8.97	-24.44	-28.12	-13.26	-21.22	-12.27
PCS-170 x VP-1	0	-11.24	6.76	-12.63	-30.92	-34.29	14.79**	6.12	18.18**
PCS-170 x DPC-9	-11.95	-15.17	2.03	-26.47	-27.08	-29.46	-8.51	-12.24	-2.27
PCS-171 x VP-1	21.55	18.62**	16.22**	31.04**	23.2	-22.62	.0.49	-1.44	-6.82
PCS-171 x DPC-9	-12.26	-17.58	-8.11	4.51	-13.82	-16.63	-14.35	-19.11	-17.27
VP-1 x DPC-9	11.55	2.42	14.19**	1.15	-20.52	-23.11	13.16*	8.89	11.36

** : Significant at 1% level;* *** : Significant at 5% level*

Table 2 **Heterosis, heterobeltiosis and standard heterosis for primary spike length, number of effective spike/plant, 100-seed weight and seed yield in castor**

Cross	Primary spike length (cm)			No. of effective spikes/plant			100 seed weight (g)			Seed yield/plant (g)		
	Mid	*Better*	*Check*	*Mid*	*Better*	*Check*	*Mid*	*Better*	*Check*	*Mid*	*Better*	*Check*
Haritha X Kranthi	-2.14	-6.00	15.56	-11.06	-16.2	16.03	-3.18	-6.17	-1.30	18.52**	16.36**	17.65**
Haritha X Kiran	-8.88	-15.73	-4.58	-28.7	-35.6	-21.15	4.23	-2.63	-3.90	21.60**	10.55	11.76*
Haritha X PCS-170	-11.34	-19.13	-8.42	-1.29	-19.9	-1.92	-8.22	-11.84	-12.99	26.45**	6.91	8.09
Haritha X PCS-171	-14.2	-22.2	-11.90	7.59	-14.66	4.49	-8.97	-13.16	-14.29	4.48	-10.91	-9.93
Haritha X VP-1	6.90	1.02	14.40	36.12	19.37	46.15**	9.63	7.89*	6.49	41.68**	25.45**	26.84**
Haritha X DPC-9	14.97	13.79	28.86**	17.45	10.99	35.90**	6.94*	1.32	0.0	34.69**	20.73**	22.06**
Kranthi x Kiran	-58.85	-63.33	-54.91	-9.19	-22.22	7.69	3.40	-6.17	-1.30	-13.47	-20.00	-22.06
Kranthi x PCS-170	-38.00	-45.46	-32.95	13.43	-12.04	21.79	17.88**	9.88**	15.58**	6.81	-8.30	-10.66
Kranthi x PCS-171	-28.45	-37.42	-23.06	14.63	-12.96	20.51	4.00	-3.7	1.30	,1.53	-14.72	-16.91
Kranthi x VP-1	-11.81	-19.75	-1.34	17.22	-2.31	35.26**	-1.68	-6.17	-1.30	22.43**	10.19	7.35
Kranthi x DPC-9	-3.16	-7.89	13.24	-1.04	-11.57	22.44	2.01	-6.17	-1.30	13.87*	3.77	1.10
Kiran x PCS-170	-54.04	-54.72	-56.44	26.01*	11.69	10.26	10.29**	7.14	-2.60	3.61	-4.44	-20.96
Kiran x PCS-171	-10.01	-11.92	-15.25	63.91**	41.56**	39.74**	-2.22	-4.35	-14.29	3.58	-3.56	-20.22
Kiran x VP-1	-2.57	-4.78	-4.03	0.67	-2.6	-3.85	24.64**	18.21**	12.99**	23.57**	20.00**	-0.74
Kiran x DPC-9	-32.02	-36.52	-29.59	1.23	-3.53	5.13	10.45**	8.82*	-3.90	8.35	6.67	-11.76
PCS-170 x PCS-171	-14.14	-14.71	-20.38	-10.82	-13.45	-33.97	0.72	0.00	-9.09	5.21	4.12	-25.74
PCS-170 x VP-1	9.18	5.15	5.98	23.19	12.5	3.85	8.64*	5.98	1.30	26.37**	19.81*	-6.62
PCS-170 x DPC-9	-20.97	-27.23	-19.28	1.04	-14.12	-6.41	-2.90	-4.29	-12.99	-5.39	-11.47	-29.04
PCS-171 x VP-1	-3.42	-7.57	-6.83	-6.25	-16.67	-23.08	-4.63	-7.61	11.69	19.21**	14.15	-11.03
PCS-171 x DPC-9	-15.50	-22.66	-14.22	-13.48	-28.24	-21.79	18.25**	17.39**	5.19	2.91	-2.75	-22.06
VP-1 x DPC-9	-5.48	-9.79	0.06	-3.18	-10.59	-2.56	4.52	0.54	-3.90	27.91**	26.15**	1.10

* : Significant at 1% level; ** : Significant at 5% level

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Modified triple test cross analysis in castor, *Ricinus communis* L.

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Abstract

Six elite pistillate lines of castor (VP-1, PPL-1008, PPL-1010, PPL-1018, PPL-1024 and PPL 1038) were crossed with two extreme types as testers PCS-274 (red stem, zero bloom, non-spiny capsule, early maturing, dwarf) and PCS-511 (green stem, double bloom, spiny capsule, late maturing and tall) during winter season of 2008 at RARS, Palem. The resulting 12 castor hybrids were evaluated along with their parents for various yield and yield contributing traits during rainy season of 2009 at ARS, Darsi. The data were subjected to modified triple test cross analysis to estimate the additive (D) and dominance (A) variance and to detect the presence or absence of epistasis. The results indicated that the estimates of additive component (D) were greater in magnitude for all the eight characters studied indicating the partial dominance. Epistatic component of genetic variation was found to be present for all the characters and these characters can be improved through recurrent selection procedures.

Keywords: Castor, modified triple test cross, epistasis

Introduction

Castor is an important non-edible oilseed crop of Andhra Pradesh, mainly grown in Mahaboobnagar, Nalgonda, Ranga Reddy, Kurnool, Kadapa and Prakasam districts. The productivity of the crop in the state is 511 kg/ha, which is far below the national average of 1339 kg/ha. So, there is an urgent need to increase the yield and productivity. Yield is governed by complex phenomenon and breeder has to understand thoroughly the gene action controlling the traits. Various biometrical designs are vague to understand the gene action controlling different traits which assume absence of epistasis, which is an integral part of genetic variance.

One of the best designs for detection of epistasis is triple test cross (Kearsey and Jinks, 1968). Though this design is efficient, it requires four populations P_1, P_2, F_1 and F_2. Hence, it is a tedious and time consuming process. Jinks *et al.* (1969) proposed a modification for this model in which a set of lines are crossed to two extreme testers. This design is simpler, instead of F_2 population a set of inbred lines (Pi) are crossed to two testers (L_1 and L_2) of opposite extreme to generate $\bar{L}_{1i}$ and $\bar{L}_{2i}$ families. Thus it requires only tester parents, lines and F_1s. In the present investigation, an attempt was made to assess the genetic components of variance *viz.*, additive, dominance and epistasis in castor using the modified triple test cross analysis.

Materials and methods

Six elite pistillate lines of castor (VP-1, PPL - 1008, PPL-1010, PPL-1018, PPL-1024 and PPL 1038) and two extreme testers PCS-274 (red stem, zero bloom, non-spiny capsule, early maturing, dwarf) and PCS-511 (green stem, double bloom, spiny capsule, late maturing and tall) were crossed to generate 12 F_1 hybrids during winter season of 2008 at RARS, Palem. The F_1 hybrids along with their parents were evaluated at ARS, Darsi during rainy season of 2009 in a randomized block design, replicated twice with a spacing of 90 cm x 60 cm. Each entry was sown in four rows with each row of 6 m length. Ten plants were randomly selected from each entry and replication and observations were recorded on number of nodes up to primary spike, plant height up to primary spike, number of effective spikes/plant, 100 seed weight (g) and oil content (%). Seed yield, days to 50% flowering and days to maturity were recorded on plot basis. The data were subjected to modified triple test cross analysis (Jinks *et al.*, 1969).

Results and discussion

Epistatic gene action is an integral part of genetic architecture and to test it, modified triple test cross model was adopted using two extreme testers which differed morphologically for several characters. The results obtained (Table 1) gave the information on additive, dominance and epistatic components of genetic variance without any inflation or deflation.

The results revealed that variance due to sums ($\bar{L}_{1i}$ + $\bar{L}_{2i}$) were significant for all the eight traits studied. Hence it can be concluded that additive component of genetic variance (D) governed all the characters studied. The analysis of variance due to differences ($\bar{L}_{1i}$ - $\bar{L}_{2i}$) measuring the dominance component (H) was significant for all the traits. But the additive (D) component was higher than the dominance component. The variance due to epistasis ($\bar{L}_{1i}$ + $\bar{L}_{2i}$ - P_i) was significant for yield and yield contributing traits indicating the presence of epistasis in the genetic variance. Thus to have a clear picture about the genetic systems controlling these characters if a procedure assuming no epistasis had been used.

The degree of dominance $(H/D)^{1/2}$ revealed the preponderance of partial dominance for days to 50% flowering, days to maturity, plant height, number of nodes up to primary spike, number of effective spikes/plant, 100 seed weight, seed yield/plot and oil content. Similar results were reported by Venkata Ramana Rao *et al.* (2009) in castor. Also, Satyanarayana *et al.* (2001), Rao *et al.* (2004) and Shankar *et al.* (2006) reported the significance of epistasis in sunflower for yield and its contributing traits.

Therefore, it may be concluded that all the three components of genetic variance i.e., additive, dominance and epistasis were playing significant role in controlling the traits. So the breeding programme to be followed should not only exploit fixable gene effects but also ponder the non-additive gene effects for further improvement of base population and broadening the genetic base.

Table 1 Detection of additive, dominance and epistatic components of variation in castor using modified TTC model

Source	d.f	Days to 50% flowering	Days to maturity	No. of nodes up to primary spike	Plant height (cm)	No. of effective spikes/plant	100 Seed weight (g)	Seed yield/plot	Oil content (%)
Mean									
PCS 274 (L_1)		45.0	84.0	11.4	54.60	2.4	29.1	856	39.8
PCS 511 (L_2)		59	109.6	17.2	112.25	7	22.4	1828.5	49.05
Additive									
Replications	1	11.45	6.48	0.67	2.78	0.08	0.02	11412.50	6.68
Sums, $\bar{L}_{1i}$ + $\bar{L}_{2i}$ (Additive)	7	45.67**	54.47*	14.18**	370.14**	2.65**	44.38*	114565.50**	58.45**
Sums x blocks (Error)	7	3.35	12.65	1.97	45.75	0.31	7.25	14286.28	4.78
Dominance									
Replications	1	4.25	26.57	1.56	44.25	0.12	0.07	115.65	4.46
Differences, $\bar{L}_{1i}$ -$\bar{L}_{2i}$ (Dominance)	7	24.48*	47.89**	1.21**	279.32**	0.89*	26.85*	89540.78*	27.84*
Differences x blocks (Error)	7	4.93	5.98	0.09	34.15	0.19	8.57	14210.99	5.19
Epistasis									
Replications	1	7.32	7.49	1.47	4.48	0.02	3.98	32872.25	8.39
Sums, $\bar{L}_{1i}$ + $\bar{L}_{2i}$ - P_i (Additive)	7	40.43*	154.85**	5.74*	679.63**	1.69**	50.75*	212583.00*	44.9*
Sums x blocks (Error)	7	8.69	15.81	1.42	35.09	0.25	10.91	35216.14	9.65
Degree of dominance $(H/D)^{1/2}$		0.75	0.94	0.34	0.78	0.64	0.87	0.78	0.69

Note: L_1 and L_2 in the ANOVA represent the two testers employed, whereas P_i represent the pistillate lines

However, the experiment was conducted at one location for only one year, the estimates of additive and dominance components are confounded with environmental effects (locations, years, etc.). The characters which showed absence of epistasis may give evidence of epistasis under other environmental conditions. Similarly the characters which showed the presence of significant epistasis may not do so if tested under other environments. Therefore, more elaborate experiments, conduced at different locations for more than one year will give a clear picture about the genetic systems controlling these characters and help in developing more efficient breeding procedures (Subbaraman and Rangasamy, 1989).

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Analysis of genetic divergence in castor, *Ricinus communis* L.

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Abstract

Seventy genotypes were evaluated for seven metric traits to quantify genetic diversity existing among them by Mahalanobis D^2 statistic. The genotypes fell into 16 clusters. Maximum inter cluster distance was observed between cluster XI and XIV (D=10.73) followed by clusters X and XIV (D=10.65) and cluster VIII and XIV (D=10.3). Among the seven characters studied, plant height contributed maximum (64.8) towards genetic divergence followed by days to 50% flowering (10.4), primary spike length (8.7), seed yield/plant (7.3). The genotypes of cluster XIV exhibited highest mean value for plant height and number of nodes while the genotypes of cluster X recorded lowest mean for number of nodes and spike length. Genotypes of cluster X recorded lowest mean for the traits plant height and 100 seed weight. The relative divergence of each cluster from other clusters (inter-cluster divergence) indicated high order of divergence between clusters XI and XIV (D=10.73).

Keywords: Castor, genetic divergence

Introduction

Genetic improvement mainly depends upon the amount of genetic variability present in the population. Information on the nature and degree of genetic divergence would help the plant breeder in choosing the right parents for breeding programme (Vivekanandan and Subramanian, 1993). For any hybridization programme, parents having high variability and diversity are selected for seed yield. The crosses between genetically diverse parents are likely to produce high heterotic effect and more variability in segregating generations. Multivariate analysis using Mahalanobis D^2 statistic (1936) is a valuable tool in qualifying the degree of divergence among biological population. This has been successfully utilized in castor to classify the genotypes and determine their interrelationships by many workers (Sevagaperumal *et al.*, 2000, Lakshamma *et al.*, 2002 and Zareena Begum *et al.*, 2009). The present study was carried out to ascertain the nature and magnitude of genetic divergence among castor germplasm collected from Directorate of Oilseeds Research, Hyderabad.

Materials and methods

Seventy castor germplasm accessions obtained from Directorate of Oilseeds Research, Hyderabad comprised the experimental material in the present study. These genotypes including two standard checks *viz.*, Kranthi and Haritha were raised in a randomized block design with three replications, each genotype raised in two rows of 6.0 m length at spacing of 90 cm x 60 cm at Regional Agricultural Research Station, Palem during winter season of 2009. The recommended agronomic practices were followed. Observations were recorded on five random plants of each genotype per replication for seven quantitative traits. Genetic divergence was estimated by Mahalanobis D^2 statistic (1936) and the genotypes were grouped. Average intra and inter cluster distances were estimated as per the procedure outlined by Singh and Chaudhary (1977).

Results and discussion

The analysis of variance revealed significant differences among the genotypes for each character, indicating the existence of variability among the genotypes for the characters studied. Based on the relative magnitude of D^2 values, 70 genotypes were grouped into 16 clusters (Table 1). Cluster I had 18 genotypes followed by cluster II which had 16 genotypes. Cluster VI had 11 genotypes while cluster V had 7 genotypes. Cluster XIV had 5 genotypes while three genotypes were grouped in XV genotypes. Clusters III, IV, VII, VIII, IX, X, XI, XII, XIII and XVI had single genotype in each cluster. The pattern of group constellations proved that significant amount of variability existed.

The intra and inter cluster distance (Table 2) revealed that there is no genetic diversity among the genotypes in almost all clusters except clusters I, II, V, VI, XIV and XV which indicates that unidirectional selection practiced in the past might have resulted in uniform features with less divergence between the genotypes. The maximum intracluster distance (D=3.06) was observed in cluster VI. Selection with this cluster might be exercised based on the highest mean for the desirable traits.

The relative divergence of each cluster from other clusters (inter-cluster divergence) indicated high order of divergence between clusters XI and XIV (D=10.7) followed by clusters X and XIV (D=10.7) and cluster VIII and XIV (D=10.3). The hybridization between genotypes from these clusters will result in maximum hybrid vigour and highest number of useful segregants for metric traits. Hybridization between genetically distant genotypes to generate promising breeding material has been suggested by Vivekanandan and Subramanian (1993).

The contribution of individual characters towards the divergence (Table 3) indicated that the plant height exhibited the maximum contribution (64.8), followed by days to 50% flowering (10.4), primary spike length (8.7), seed yield/plant (7.2), 100 seed weight (4.4) and effective spike length (3.2) towards total genetic divergence. The trait number of nodes (1.3) showed negligible contribution towards genetic divergence. Thus, four characters plant height, days to 50% flowering, spike length and seed yield were important since they contributed 91.2% towards total divergence.

There was a wide range of variation in the cluster mean value for most of the characters under study (Table 4). For the trait plant height, genotypes of cluster XIV (112.7 cm) recorded highest mean and lowest mean was recorded by genotypes of cluster XI (36.1 cm). Genotypes of cluster V (61.4) recorded highest mean for days to 50% flowering while mean was lowest in cluster XVI (43.7). For the trait number of nodes, genotypes of cluster XIV (17.12) recorded highest mean and lowest mean was observed in cluster X (10.5).

Table 1 Clustering pattern among 70 castor genotypes

Cluster	No. of genotypes	Name of genotypes
I	18	RG-247, RG-1096, RG-18, RG-1096, RG-247, RG-226, RG-2813, PCG-193, PCG184, RG-43, RG-25, RG-1713, PCG-191, RG-1482, RG-1826, PCG-195, PCG-185, RG-3068
II	16	Haritha, Kranthi, RG-122, RG-1337, RG-1628, RG-90, RG-3082, RG-1701, RG-2752, RG-941, RG-1713, RG-172, PCG-194, PCG-206, RG-1427, RG-1526
III	1	RG-25
IV	1	RG-409
V	7	PCG-215, RG-51, RG-2134, PCG-214, PCG-204, RG-1117, RG-122,
VI	11	RG-235, RG-72, RG-111, RG-430, RG-68, PCG-213, RG-297, RG22, RG1721, RG-1117, RG-2727
VII	1	RG-2162
VIII	1	PCG-202
IX	1	RG-1826
X	1	PCG-216
XI	1	PCG-205
XII	1	PCG-192
XIII	1	PCG-210
XIV	5	RG-2773, RG-2763, RG-2005, RG-1634, RG-52
XV	3	PCG-212, RG-17, RG-232,
XVI	1	PCG-178

In cluster XV, highest mean for primary spike length (61.8 cm), was observed and it was lowest in cluster X (17.1 cm). For the trait number of effective spikes/plant, genotypes of cluster XII (11.5) recorded highest mean and genotypes of cluster IV (4.7) recorded lowest mean. In cluster IX (29.0), highest mean for 100 seed weight was observed while it was lowest in cluster XI (22.3). Genotypes of cluster XVI (109.7) recorded highest mean for the character seed yield/plant while mean was lowest in cluster VIII (53.7). The genotypes of cluster XIV exhibited highest mean value for plant height and number of nodes while the genotypes of cluster X recorded lowest mean for number of nodes and spike length. Genotypes of cluster X recorded lowest mean for the traits plant height and 100 seed weight. The genotypes of cluster XVI recorded highest means for seed yield/plant and lowest mean for days to 50% flowering. Thus, these genotypes hold great promise as parents to obtain promising hybrids and create further variability for these characters. Crosses among diverged parents are likely to yield desirable combinations. Therefore, a crossing programme should be initiated between the genotypes belonging to different clusters. Two important points to be considered: (i) Choice of particular clusters from which genotypes are to be used as parents in crossing programme and (ii) Selection of genotypes from selected groups. The greater the distance between two clusters, the wider the genetic diversity among the parents to be included in hybridization programme. Parents combining high yield potential with wide genetic diversity are likely to yield superior segregants within a short period (Vivekanandan and Subramanian, 1993). The genotypes with high mean value on any cluster can either straight away be used for adoption or can be used in hybridization for yield improvement.

Table 2 Intra (diagonal) and inter cluster distance of D values of 70 castor genotypes

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X	Cluster XI	Cluster XII	Cluster XIII	Cluster XIV	Cluster XV	Cluster XVI
Cluster I	2.1	4.76	2.7	2.71	5.79	3.85	2.43	2.75	2.5	2.99	2.74	2.58	2.7	9.09	3.2	3.27
Cluster II		2.39	3.06	3.02	3.33	3.29	5.05	6.24	3.93	6.15	4.36	4.44	4.51	5.42	5.17	4.5
Cluster III			0	2.2	3.69	2.41	2.66	3.92	2.8	4.36	3.91	2.46	2.23	6.99	3.5	3.45
Cluster IV				0	4.49	2.96	3.33	4.09	1.82	3.75	4.22	3.32	3.38	7.4	3.65	2.97
Cluster V					2.3	3.88	5.89	6.84	5.28	7.34	7.25	5.54	5.01	4.38	6.26	6.12
Cluster VI						3.06	4.28	4.88	3.82	5.36	5.21	3.73	3.9	6.66	4.57	4.45
Cluster VII							0	3.51	2.72	2.7	2.02	2.81	1.85	9.29	3.42	2.72
Cluster VIII								0	4.02	3.68	2.65	3.63	3.74	10.3	3.57	5.17
Cluster IX									0	2.98	3.85	2.94	2.62	8.35	3.4	2.31
Cluster X										0	2.38	4.35	3.96	10.65	4.51	2.97
Cluster XI											0	3.71	3.4	10.73	4.02	3.82
Cluster XII												0	2.12	8.63	2.64	3.5
Cluster XIII													0	8.41	3.3	3.4
Cluster XIV														2.88	9.24	8.97
Cluster XV															2.31	4.53
Cluster XVI																0

Table 3 Contribution of each character to divergence

Source	Times ranked first	Contribution %
Days to 50% flowering	251	10.39
Plant height (cm)	1565	64.8
No. of nodes up to primary spike	31	1.28
Primary spike length (cm)	211	8.74
No. of effective spikes/plant	77	3.19
100 seed weight (g)	105	4.35
Seed yield/plant	175	7.25

Table 4 Cluster means for different characters

Cluster	Days to 50% flowering	Plant height (cm)	No. of nodes upto primary spike	Primary spike length (cm)	Effective spikes/plant	100 seed weight (g)	Seed yield/plant (g)
Cluster I	52.91	48.3	13.8	35.2	8.1	26.2	76.5
Cluster II	49.5	78.3	15.2	44.7	6.6	25.9	78.5
Cluster III	56.6	62.9	15.4	38.5	8.6	24.0	80.6
Cluster IV	48.3	62.1	14.1	34.5	4.7	27.0	70.6
Cluster V	61.3	87.8	15.6	35.7	8.1	26.6	78.6
Cluster VI	53.7	69.1	14.5	37.3	9.4	24.6	69.0
Cluster VII	57.3	47.4	14.7	33.6	6.4	22.6	101.3
Cluster VIII	59.3	38.2	13.8	30.2	9.0	27.6	53.6
Cluster IX	49.3	56.2	12.5	38.2	5.0	29.0	90.0
Cluster X	50.0	42.8	10.5	17.1	4.8	24.6	92.0
Cluster XI	56.3	36.0	14.9	24.1	7.3	22.3	85.3
Cluster XII	52.6	49.0	15.1	57.9	11.4	26.0	84.6
Cluster XIII	60.0	52.9	15.2	43.7	8.7	26.6	101.6
Cluster XIV	57.6	112.6	17.1	47.4	7.1	26.4	73.2
Cluster XV	55.4	44.5	13.4	61.7	6.0	25.4	70.0
Cluster XVI	43.6	54.9	13.8	34.2	6.2	24.0	109.6

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Combining ability analysis in castor, *Ricinus communis* L.

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Abstract

Seven elite lines consisting of released varieties (Haritha, Kranthi, Kiran), advanced breeding lines (PCS-170, PCS-171) and pistillate lines (VP-1 and DPC-9) were crossed in diallel method excluding reciprocals. The resultant 21 hybrids were evaluated along with their parents in a randomized block design, replicated thrice. The analysis of variance for combining ability revealed significant differences among the genotypes, indicating wide diversity in the material studied. The mean squares due to general and specific combining ability (*gca* and *sca*) were highly significant for all traits indicating that both additive and non-additive types of gene action were involved in the inheritance of these traits. The *gca* effects of the parents revealed that three parents Haritha, Kranthi and VP-1 were promising general combiners for seed yield and other yield contributing traits. Based on the sca effects and *per se* performance four hybrids *viz.*, Haritha x DPC-9, Haritha x VP-1, Haritha x Kiran and Haritha x PCS-170 were identified as promising for seed yield/plant and other characters.

Keywords: Combining ability, diallel, Castor

Introduction

Castor (*Ricinus communis* L.) plays an important role in the country's vegetable oil economy. The crop is grown for its non-edible oil (45-50% oil in seeds) which is completely biodegradable with its utilization in several fields such as manufacturing lubricants, printing inks, nylon fibers, hydraulic fluids, cosmetics, varnishes, pharmaceuticals and similar others. Castor cake is considered to be excellent organic manure. Eri-silk culture is an emerging field wherein the castor leaves are fed to eri-silk worms. Besides meeting the domestic requirements towards its use in various fields and a variety of diversified products, the country is presently dominating international castor oil market. Seed yield is a complex character involving number of components each of which is polygenically controlled and thus susceptible to environmental fluctuations. Thus selection of parents for hybridization is therefore, a complex problem. Combining ability analysis helps in identification of suitable parents for exploitation in breeding programmes. With a view to identify the lines and crosses with good combining ability for exploitation of heterosis, the present investigation was under taken.

Materials and methods

The experimental material consisted of seven elite lines including released varieties (Haritha, Kranthi, Kiran), advanced breeding lines (PCS-170, PCS-171) and pistillate lines (VP-1 and DPC-9). These lines were crossed in a diallel method excluding reciprocals during winter season of 2008 at Regional Agricultural Research Station, Palem. The resultant 21 hybrids were evaluated along with their parents in a randomized block design, replicated thrice at Regional Agricultural Research Station Farm, Palem during rainy season of 2009. Each entry was sown in two rows with a row length of 6 m. Five plants were randomly selected from each entry and replication and observations were recorded on plant height, number of nodes upto primary spike, primary spike length, number of effective spikes/plant, 100 seed weight and seed yield/plant. Days to 50% flowering was recorded on plot basis. A standard package of practices was followed for growing the crop. Data obtained was subjected to diallel method II analysis to estimate general and specific combining ability effects and their respective variances.

Results and discussion

Analysis of variance revealed significant differences for all characters, indicating wide genetic variability among genotypes (Table 1). The mean squares due to general and specific combining ability (gca and sca) (Table 2) were highly significant for all traits. Thus, both additive and non-additive types of gene action were involved in the inheritance of these traits.

Hence, improvement of these traits may be brought about by recurrent selection or selective diallel mating system. Lavanya *et al.* (2006), Chandramohan *et al.* (2006) and Patel *et al.* (2007) reported similarly.

Among the parents studied Haritha, Kranthi and VP-1 were good combiners as indicated by their significant positive *gca* effects (Table 3). All these parents contribute maximum positive alleles for the increase of seed yield/plant. The Haritha is a good general combiner for seed yield/plant, number of effective spikes/plant, primary spike length and days to 50% flowering. The parent Kranthi is good general combiner for seed yield/plant, 100 seed weight, number of effective spikes per plant whereas VP-1 is for seed yield/plant, 100 seed weight, primary spike length, plant height and days to 50% flowering. These parents can be extensively used in breeding programme for getting better combination for seed yield and other agronomic characters because of their capacity to transmit their characters to the off springs. Similar results were reported by Solanki *et al.* (2004) and Venkataramana *et al.* (2005).

Among the hybrids, four (Haritha x DPC-9, Haritha x VP-1, Haritha x Kiran and Haritha x PCS-170) were identified as promising hybrids based on the specific combing ability and *per se* performance . Of which, three combinations *viz.*, Haritha x DPC-9, Haritha x Kiran and Haritha x PCS-170 had one parent as good general combiner while the other parent was poor combiner, while in other cross Haritha x VP-1 both the parents were good combiners (Table 4). Solanki and Joshi (2000) and Kavani *et al.* (2001) also reported similar results.

Table 1 Analysis of variance for seed yield and yield components in castor

Source	df	Days to 50% flowering	Plant height	No. of nodes upto primary spike	Primary spike length	No. of effective spikes/plant	100 seed weight	Seed yield/plant
Replicates	2	2.726	103.14**	0.43	4.15	2.03*	0.77	22.96
Treatments	27	55.46**	506.67**	7.19**	374.21**	4.00**	12.77**	631.76**
Parents	6	60.31**	899.93**	2.88*	121.91**	4.69**	9.14**	361.20**
Hybrids	20	56.45**	399.70**	8.84**	416.12**	3.91*	13.63**	655.18**
Parent vs Hybrid	1	6.67	286.29**	0.02	1050.02**	1.57	17.39**	1786.67*
Error	54	3.96	18.47	1.02	30.22	0.62	1.23	42.19

Table 2 Estimates of general and specific combining variances and proportionate gene action for seven characters in castor

Source	df	Days to 50% flowering	Plant height	No. of nodes upto primary spike	Primary spike length	No. of effective spikes/plant	100 seed weight	Seed yield/plant
GCA	6	22.76**	483.50**	1.52**	251.62**	2.69**	5.81**	620.63**
SCA	21	17.26**	78.99**	2.64**	88.48**	0.94**	3.81**	93.43**
Error	54	1.32	6.157	0.34	10.075	0.207	0.413	14.066
σ^2 *gca*		2.38	53.03	0.13	26.83	0.27	0.60	67.39
σ^2 *sca*		15.94	72.84	2.30	78.41	0.73	3.40	79.36
σ^2 *gca* / σ^2 *sca*		0.15	0.72	0.05	0.34	0.37	0.17	0.85

Table 3 General combining ability (*gca*) effects of parents for seven characters in castor

Parent	Days to 50% flowering	Plant height	No. of nodes upto primary spike	Primary spike length	No. of effective spikes/plant	00 seed weight	Seed yield/plant
Haritha	-0.71*	9.13**	0.58**	7.05**	0.44**	-0.01	14.58**
Kranthi	-0.53	9.73**	-0.12	1.10	0.88**	1.42**	3.76**
Kiran	2.58**	-3.92**	0.26	-7.07**	-0.06	-0.38	-3.27**
PCS-170	1.54**	-6.40**	0.35	-5.39**	-0.58**	-0.31	-7.97**
PCS-171	-2.04**	-4.62**	-0.46*	-3.12**	-0.67**	-1.01**	-9.78**
VP-1	-1.04**	-7.37**	-0.10	3.98**	-0.03	0.65**	3.91**
DPC-9	0.21	3.46**	-0.49**	3.44**	0.02	-0.35	-1.23
g_i	0.35	0.76	0.17	0.97	0.14	0.19	1.15

Table 4 Specific combining ability (*sca*) effects of crosses for seven characters in castor

Cross	Days to 50% flowering	Plant height	No. of nodes upto primary spike	Primary spike length	No. of effective spikes/plant	100 seed weight	Seed yield/plant
Haritha x Kranthi	3.23**	-6.51**	0.60	4.42	-0.81*	-0.85	5.14
Haritha x Kiran	-0.88	5.61*	0.75	1.33	-1.79**	0.30	6.84*
Haritha x PCS-170	-1.84	-10.11**	-0.74	-2.44	-0.27	-2.11**	8.21*
Haritha x PCS-171	1.08	13.78**	1.21*	-6.62*	0.16	-1.74**	-6.31
Haritha x VP-1	3.08**	-4.77*	-0.29	0.64	1.68**	1.92**	13.32**
Haritha x DPC-9	-2.84**	-2.44	0.43	9.08**	1.09**	1.27*	14.14**
Kranthi x Kiran	3.27**	-3.45	-0.14	-20.22**	-0.73	-0.48	-13.01**
Kranthi x PCS-170	3.31**	-13.91**	0.50	-9.90**	0.52	3.78**	2.03
Kranthi x PCS-171	-3.77**	-1.42	-0.35	-6.77*	0.55	0.82	-1.82
Kranthi x VP-1	-2.77**	9.17**	0.36	-2.02	0.68	-1.52**	6.47
Kranthi x DPC-9	-2.03**	7.29**	-1.86**	6.49*	-0.05	-0.51	5.95
Kiran x PCS-170	0.19	-11.68**	-1.52**	-14.55**	0.88*	0.93	-0.27
Kiran x PCS-171	5.12**	-7.43**	4.33**	5.68*	2.51**	-1.37*	2.21
Kiran x VP-1	-4.55**	4.62*	-2.43**	4.70	-0.40	3.96**	6.18
Kiran x DPC-9	4.53**	-0.68	-0.98	-8.73**	0.01	0.64	1.32
PCS-170 x PCS-171	-5.51**	1.68	-1.83**	1.21	-0.81*	-0.11*	1.92
PCS-170 x VP-1	-0.18	-0.17	2.28**	8.49**	0.51	0.89	5.55
PCS-170 x DPC-9	-3.77**	-7.40**	-0.34	-4.77	-0.08	-1.77**	-9.64**
PCS-171 x VP-1	8.08**	6.75**	-0.57	-0.78	-0.79*	-1.74**	3.36
PCS-171 x DPC-9	-5.18**	0.38	-1.72**	-4.27	-0.78*	3.60**	-1.49
VP-1 x DPC-9	4.82**	-1.69	2.12**	-3.59	-0.42	-0.41	5.81
S_{ij}	1.03	2.22	0.52	2.84	0.40	0.57	3.36

When we compare *per se* performance with *gca* effects of parents/*sca* effects of hybrids, some crosses were common but occupied different positions. It is suggested that selection of cross combination should be made on the basis of *per se* performance and *sca* effects. It would be more useful if the crosses showing high *sca* effects involving parents with high *gca* effects. Most of the crosses showing high *sca* effect for different characters involved atleast one good general combiner for that trait. Thus, either additive x additive and or additive x dominance genetic interaction was predominant in the material under study. In such cases where non-additive gene effects play an important role in association with additive components, the recurrent selection or reciprocal recurrent selection can be used to exploit both the components simultaneously.

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Heterosis and combining ability analysis for seed yield and its components in castor, *Ricinus communis* L.

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Abstract

A Line x Tester analysis, using three female (line) and eight male (tester) parents, was conducted on seed yield and some component traits in castor (*Ricinus communis* L.). The results revealed that mean sum of squares due to general and specific combining ability were significant, suggesting the importance of both additive and non-additive components of genetic variance. Among the females, SKP 84 and males, J 368 and SKP 215 were good general combiners exhibiting high *gca* effects for seed yield and some of its component traits. The crosses SKP 84 x JI 355, JP 103 x SKI 291 and JP 103 x JI 273 had high *sca* effects for seed yield/plant. Amongst, SKP 84 x JI 355 expressed the highest *sca* effect for seed yield/plant along with the highest *per se* performance in F_1. The hybrid SKP 84 x JI 342 expressed the highest heterotic values over mid (50.7%) and better parent (42.6%) for seed yield/plant.

Keywords : Castor, combining ability, heterosis

Introduction

Among several non-edible oilseed crops cultivated in India, Castor (*Ricinus communis* L.) is an important oil-producing crop of India. Seed yield in castor is known to be a polygenic controlled complex character and determined by number of quantitatively inherited yield components. The general and specific combining ability estimates are useful to assess the nicking ability of parents and at the same time helps in identification of potential parents and crosses which supply basic material on which the success of a breeding programmme rests. Also these estimates elucidate the nature and magnitude of gene effects in controlling various traits. The parents with high *gca* effects are utilized to produce synthetic varieties, while the lines showing superior effects in specific combinations are used in hybrid breeding. The line x tester mating design is used to estimate the combining ability of parents and cross combinations. The present study was, therefore, conducted to estimate combining ability of parents as well as nature and magnitude of heterosis for yield and its components in castor.

Materials and methods

Three pistillate lines (female) *viz.*, JP 103, JP 104 and SKP 84 and eight male parents *viz.*, J 220, J 273, J 342, J 355, J 368, J 378, SKI 215 and SKI 291 were selected on the basis of desirable agronomic characters and wide genetic base. These genotypes have also resistance to one or more diseases. They were crossed in line x tester mating design. The 24 hybrids and their 11 parents were sown in randomized block design with three replications at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh during 2009-2010. Each entry was assigned double row plots of 6.0 m length. Row to row and plant to plant spacing was 90 cm and 60 cm, respectively. Recommended agronomic practices of the region were followed to grow the crop. The observations were recorded for nine characters *viz.*, height up to primary raceme (cm), effective length of primary raceme (cm), number of nodes up to primary raceme, number of capsules on primary raceme, days to 50% flowering of primary raceme, number of effective raceme/plant, 100 seed weight (g), oil content (%) and seed yield/plant (g) on five randomly selected plants. Mean data were used for statistical analysis. The total variation among F_1s was partitioned further into variance due to lines, testers and their interaction effects and used for combining ability analysis (Kempthorne, 1957). The degree of heterosis in F_1 over mid parent (Jinks, 1983) and better parent (Turner, 1953) was calculated for individual character and expressed in %.

Results and discussion

The mean squares due to hybrids were significant for all the traits (Table 1). The lines (female) and tester (males) varied significantly for their general combining ability for all the characters. The hybrids also showed significant variation in specific combining ability as judged from line x tester interaction mean sum of squares for all the traits. The *gca* variance ($\sigma^2 gca$) was found to be higher than *sca* variance ($\sigma^2 sca$) for effective length of primary raceme, number of capsules on primary raceme, number of effective racemes/plant and 100 seed weight indicating the predominance of additive component of heritable variation. The $\sigma^2 gca/\sigma^2 sca$ ratio was substantially less than unity for height up to primary raceme, days to 50% flowering of primary raceme, oil content and seed yield/plant suggesting that these characters were governed predominantly by non-additive components of heritable variation. The results indicated that both the additive and non-additive genetic variances were important for these traits. The findings, in general, are in conformity with results reported earlier (Barad *et. al*, 2009; Gondaliya *et al.*, 2001 and Fatteh *et al.*, 1998). These observations suggest that a breeding method that can exploit both additive and non-additive genetic components would be useful. Recurrent selection method, which provides better opportunity for selection, recombination and accumulation of desired genes, should help to increase fixable as well as non-fixable types of gene effects.

The *gca* of the female (Table 2) indicated that JP 103 expressed significant gca effects for height up to primary raceme, days to 50% flowering of primary raceme and 100 seed weight. Similarly, JP 104 showed significant *gca* effects for effective length of primary raceme, number of nodes up to primary raceme, number of capsules on primary raceme and number of effective raceme/plant while, SKP 84 showed significant *gca* effects for effective length of primary raceme, number of capsules on primary raceme and seed yield/plant. Whereas the male JI 342 for effective length of primary raceme, JI 355 for number of nodes up to primary raceme, JI 368 for number of effective raceme/plant, 100 seed weight and seed yield/plant, JI378 for days to 50% flowering of primary raceme, SKI 215 for height up to primary raceme, number of capsules on primary raceme, number of effective raceme/plant and seed yield/plant and SKI 291 for effective length of primary raceme and oil content expressed the significant *gca* effects. No significant association was observed between *gca* effects and *per se* performance of the parents (data not reported) for all the characters. It is indicative of involvement of non-additive genetic effects. Thus, ability to transmit desirable characters from parent to the progeny can not be predicted from phenotypic performance alone, therefore *gca* effects should be taken into account while selecting the parents.

Three top ranking cross combinations selected on the basis of *sca* effect involved high, medium and low general combiners (Table 3). Parents were classified as high or good, medium or average and low or poor combiners on the basis of their *gca* effect. Parents with significant desirable *gca* effects were considered as high or good combiners (H), while parents showing non-significant estimates were classified as average or medium combiners (A). Poor or low combiners had undesirable significant *gca* effect (L). The crosses, SKP 84 x JI 355, JP 103 x SKI 291 and JP 103 x JI 273 had high *sca* effects for seed yield/plant. Amongst, SKP 84 x JI 355 expressed the highest *sca* effect for seed yield/plant along with the highest *per se* performance in F_1. The cross SKP 84 x SKI 215 for height up to primary raceme, SKP 84 x SKI 291 for effective length of primary raceme, JP 104 x SKI 291 for number of nodes up to primary raceme, SKP 84 x JI 342 for number of capsules on primary raceme, JP 104 x SKI 291 for days to 50% flowering of primary raceme and number of effective raceme/plant, JP 104 x JI 368 for 100 seed weight and SKP 84 x SKI 215 for oil content identified as the promising crosses with high *per se* performance and significant *sca* effects in desirable direction. The superiority of average x average, average x low, or low x low combinations for most of the characters may be due to the presence of genetic diversity among the parents and there could be some complementation indicating importance of non-additive effects. The findings were supported by several earlier reports like, Patel *et al.* (1986), Tank *et al.* (2003), Dobaria *et al.* (1992) and Dangaria *et al.* (1987).

Table 1 Analysis of variance for combining ability for seed yield and other traits in castor

Source of variations	*df*	Height up to *primary raceme* (cm)	Effective length *of primary* raceme	No. of nodes up *to primary* raceme	No. of capsules *on primary* raceme	Days to 50% *flowering of* primary raceme	No. of *effective* raceme/plant	100 seed weight	Oil content	Seed yield/ plant
Crosses	23	137.90**	94.73**	1.55**	215.04**	34.72**	6.17**	14.55**	1.90**	1304.94**
Female	2	278.35	414.54**	5.06*	1243.50**	100.54	17.18*	78.81**	0.28	4402.08*
Male	7	146.03	92.15	1.70	108.24	25.84	9.05*	12.23	1.87	1133.89
Female x Male	14	113.78**	50.34**	0.98**	121.52**	29.76**	3.16*	6.53**	2.15**	948.01**
Error	68	9.92	8.10	0.39	11.60	1.31	1.40	1.39	0.30	106.38
σ^2 *gca*		12.12	14.80	0.18	40.07	3.74	0.70	2.67	0.05	160.77
σ^2 *sca*		33.87	13.72	0.18	35.60	9.43	0.56	1.66	0.61	277.60
$\sigma^2 gca/\sigma^2 sca$		0.36	1.08	0.98	1.13	0.40	1.27	1.60	0.07	0.58

* and ** Significant at P = 0.05 and P = 0.01 level, respectively

Table 2 Estimate of gca effects for seed yield and other traits in castor

Parents	Height up to primary raceme(cm)	Effective length of primary raceme	No. of nodes up to primary *raceme*	No. of capsules on primary *raceme*	Days to 50% flowering of primary raceme	No. of effective raceme/plant	100 seed weight	Oil content	Seed yield/plant
Females									
JP 103	3.74**	-4.79**	-0.03	1.89	-1.96**	-0.40	1.36**	-0.12	-14.96**
JP 104	-2.93**	2.17*	-0.44*	5.00**	-0.17	0.97**	0.70	0.03	3.52
SKP 84	-0.81	2.63**	0.47*	3.25**	2.13**	-0.57*	-2.06**	0.09	11.44**
SE ± $(\hat{g}i)$	0.71	0.62	0.13	0.78	0.25	0.25	0.25	0.12	2.19
Males									
JI 220	-1.89	0.08	-0.10	1.99	-0.83*	0.07	0.30	-0.33	-10.20**
JI 273	-0.69	-1.47	0.13	0.21	2.72**	-1.15**	0.59	0.12	-10.81**
JI 342	1.56	4.08**	-0.10	-1.90	0.39	-0.49	0.56	0.20	6.06
JI 355	-2.56*	-2.92**	-0.88**	-1.46	-0.39	-0.49	0.03	-0.25	2.64
JI 368	-2.22	-5.03**	0.24	-6.68**	-2.28**	1.40**	1.61**	-0.89**	15.95**
JI 378	-4.67**	0.64	-0.21	1.54	-1.50**	0.51	-2.34**	0.29	-11.74**
SKI 215	8.33**	0.31	0.46*	5.10**	-0.17	1.29**	0.07	0.37	13.86**
SKI 291	2.11	4.31**	0.46*	1.21	2.06**	-1.15**	-0.83*	0.48*	-5.76
SE ± $(\hat{g}i)$	1.16	1.01	0.22	1.28	0.41	0.41	0.42	0.19	3.58

* *and ** Significant at* P = 0.05 and P = 0.01 level, respectively

The results of heterosis over mid and better parent are given in table 4. Pronounced heterotic effects were observed for seed yield/plant and number of effective raceme/plant. The cross SKP 84 x JI 342 gave the highest heterosis over mid (50.66%) as well as better (42.59%) parents for seed yield/plant. Whereas, the crosses JP 103 x JI 368 (36.59%) manifested the highest heterosis for number of effective raceme/plant over mid parent. Seven and 3 crosses manifested significant heterosis for height up to primary raceme as compare to mid and better parents, respectively. Likewise, 11 crosses over mid parent and 16 crosses over better parent found significantly superior for number of nodes up to primary raceme. The crosses JP 103 x JI 355 over mid parent and SKP 84 x JI 368 over better parent manifested the highest heterosis for height up to primary raceme, respectively. Similarly, the crosses SKP 84 x JI 273 over mid parent and SKP 84 x JI 355 over better parent showed the highest heterosis for number of nodes up to primary raceme. For days to 50% flowering of primary raceme, 16 and 20 crosses expressed significant heterosis over mid and better parent, respectively. Likewise, 10 and 1 crosses gave significant heterosis over mid and better parent for 100 seed weight, respectively. Very few or no crosses were observed significantly superior for remaining characters. High heterosis could primarily be attributed to contribution of favourable alleles by their parents. Heterosis over better parent for seed yield/plant ranged from -50.72 to 42.59% which was also reported by Lavanya and Chandramohan (2003).

Table 3 Three top ranking cross combinations on the basis of *sca* effects along with their respective *gca* status and *per se* performance for seed yield and other traits

Character	Cross	*sca* effect	*gca* status of parents	*Per se* performance in F_1
Height up to primary raceme (cm)	SKP 84 x SKI 215	1.58**	L x H	82.33
	JP 103 x JI 355	5.60**	H x L	70.00
	JP 103 x JI 273	5.38*	H x A	71.67
Effective length of primary raceme (cm)	SKP 84 x SKI 291	6.82**	H x H	61.67
	JP 104 x JI 220	5.17**	L x A	55.33
	JP 104 x JI 273	4.39*	L x A	53.00
No. of nodes up to primary raceme	JP 104 x SKI 291	-1.00**	L x H	14.33
No. of capsules on primary raceme	SKP 84 x JI 342	9.53**	H x A	76.67
	JP 104 x JI 368	6.89**	H x L	71.00
	JP 103 x JI 378	5.58*	A x A	64.67
Days to 50% flowering of primary raceme	JP 104 x SKI 291	-4.39**	A x L	44.67
	SKP 84 x JI 220	-3.46**	L x H	45.00
	JP 104 x JI 273	-3.06**	A x L	46.67
No. of effective raceme/plant	JP 104 x SKI 291	1.69*	H x L	8.67
	SKP 84 x JI 355	1.57*	L x A	7.67
100 seed wt. (g)	JP 104 x JI 368	2.59**	A x H	36.50
Oil content (%)	SKP 84 x SKI 215	1.15**	A x A	50.05
Seed yield/plant (g)	SKP 84 x JI 355	28.51**	H x A	153.70
	JP 103 x SKI 291	22.93**	L x H	113.33
	JP 103 x JI 273	18.58**	L x L	103.93

* and ** Significant at P = 0.05 and P = 0.01 level, respectively

Table 4 Summary of % heterosis for seed yield and other related traits in castor

Character	No. of crosses significantly superior to mid parent	Range	No. of crosses significantly superior to better parent	Range	Cross combination showing highest heterosis in desired direction over	
					Mid parent	Better parent
Height up to primary raceme (cm)	7	-15.22 to 28.05	3	-25.77 to 18.93	JP 103 x JI 355	SKP 84 x JI 368
Effective length of primary raceme (cm)	1	-26.15 to 13.50	0	-32.12 to -3.01	SKP 84 x SKI 291	-
No. of nodes up to primary raceme	11	-12.38 to 2.13	16	-20.00 to -2.13	SKP 84 x JI 273	SKP 84 x JI 355
No. of capsules on primary raceme	0	-38.08 to 6.50	0	-52.66 to -9.75	-	-
Days to 50% flowering of primary raceme	16	-17.93 to 6.33	20	-25.97 to -1.41	SKP 84 x JI 220	SKP 84 x JI 378
No. of effective raceme/plant	1	-45.45 to 36.59	0	-57.14 to 25.00	JP 103 x JI 368	-
100 seed wt. (g)	10	-6.80 to 18.05	1	-15.09 to 10.03	JP 103 x JI 220	JP 104 x JI 368
Oil content (%)	1	-4.83 to 1.76	0	-6.14 to 0.68	JP 104 x JI 342	-
Seed yield/plant (g)	7	-32.08 to 50.66	2	-50.72 to 42.59	SKP 84 x JI 342	SKP 84 x JI 342

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Genetic variation for some morphological characters in castor, *Ricinus communis* L.

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Abstract

A group of 100 genetically diverse germplasm, including some exotic were grown in complete randomised block design with three replications at oilseeds research farm, Kalyanpur, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur during rainy season of 2007. All the lines were classified for some important morphological characteristics namely, plant height, days to 50% flowering, stem colour, bloom character, capsule attribute, spike trait, length of a raceme, number of capsules/raceme and number of nodes/plant. Attributes, plant height, days to flowering, stem colour, length of raceme, number of capsules/ raceme and number of nodes/plant showed a high range of variation indicating the presence of wider genetic variability in the accessions. Additive genetic variance was predominantly observed with these characters. For stem colour, green predominantly appeared.

Keywords: Castor, variation, morphological characters

Introduction

Castor is a non-edible oil crop and is grown in diverse situations like semi-arid and arid zones. The crop has the great potential in India and foreign countries. The average productivity/unit area (11.5 q/ha) is much less for this oilseed, when compared with other countries like Brazil and China and so on. India occupies a very high position in cultivation and seed production programme and meets about 90% of the world's requirement of this non-edible oil crop earning above ` 2000 crores of foreign exchange through export of about 3.0 lakh t of its oil. In our country, some of the states, Gujarat, Andhra Pradesh, Karnataka, Rajashthan, Tamil Nadu is the major castor growing states while, Gujarat retains its upper edge in area, production and productivity.

In Uttar Pradesh, castor is grown normally with inter-cropping of chillies, radish, tomato, pearl millet and sorghum etc. However, castor + chillies are the very common practice in rainy season and in winter season castor is grown on bunds of the fields and wheat crop in side the fields as main crop. The work conducted in this oil crop with special reference to morphological variability is limited for improvement purposes. Consequently, it is vital to take up the present study to augment the productivity and oil content, etc., through the collection of larger variability.

Materials and methods

One hundred genotypes with some exotic entries from various sources were planted in complete randomized block design with three replications at the oilseeds research farm, Kalyanpur of C.S. Azad University of Agriculture & Technology, Kanpur in rainy season of 2007. Each genotype was sown in five rows, each row of 5 m length spaced at 90 cm apart, with check entries Type-3, Tarai - 4 and Kalpi-6. Five plants randomly chosen were tagged in each accession to record data on 9 morphological characters. Recommended dose of fertilizers and other needed cultural operations were carried out timely to have a good crop condition. Observations were recorded with respect to the characters, plant height (cm), days to 50% flowering, length of a raceme (cm), number of capsules/ raceme, capsule characters, stem colour, bloom character, spike character and number of nodes/plant to study the genetic variation for isolating promising lines.

Results and discussion

The perusal of data furnished in table 1 indicated the wider/larger genetic variability with plant height (55-200 cm), days to 50% blooming, length of a raceme (40-80 cm), number of capsules/raceme (45-75) and number of nodes/plant (15-30) symbolizing that additive genes showed their cumulative effect in expression of these characters. The larger genetic variation in the characters is much helpful to be involved the genotypes for recombination breeding (Anjani, 2001).

Stem colour: Based on the colour, genotypes were grouped in to three categories such as, green, red and pink colour. Out of 100 accessions, 62 represented green stem, 6 for red and 32 for pink. Stem colour study revealed that green stem is prominent followed by pink. Red stem appeared in less frequency. Normally, green stem is highly productive in less duration. Pink is also prominent and in most of the cases it matures in for a longer duration producing very high seed yield, Red is less productive and observed in very low frequency. Practically, there is wide scope of attempting hybridization programme within the genotypes of green stem and the genotypes possessing pink for expression of the stem colour, different gene combinations are responsible. Experiences revealed that to develop short duration varieties, green stem would be preferred, whereas, to develop late duration varieties pink should be stressed upon.

Capsule characters: Capsule trait was grouped in to two categories, spiny and non spiny. In the spiny group, 45 genotypes were marked whereas, in non spiny group 55 were observed. Presence of a spine on capsule is a highly distinguishable morphological feature in this non edible oilseed. Spiny capsule nature is predominant over non-spiny nature. Spiny nature of genotypes is easily crossable and manifested high production.

Non-spiny nature is found to be less in the number and the capable of producing high yield due to various gene combinations. Spiny character was observed to be governed by dominant alleles. Colour of the capsule was also noted in the material and normally, green capsule colour was found to be the most common morphological character. Some-times unfavourable environment was observed to disturb the colour character. However, the character is to be governed by genes as such in low intensity other characters appeared. Capsule characters are much important to isolate the genotypes of spiny nature and green in colour.

Table 1 Genetic variation for morphological attributes in castor

Attributes	Genetic variation
Plant height (cm)	55-200
Days to 50% flowering	45-90
Length of raceme (cm)	40-80
Number of capsules/raceme	45-75
Capsule characters	Spiny (80), Non spiny (20),
	Green capsule (65), Pink (35)
Stem colour	Green (62); red (6), and pink (32)
Bloom character	B0 (8); B1 (24); B2 (18); B3 (50)
Spike characters	Compact (8); Semi compact (30); Loose (62)
Number of nodes/plant	15-30

Bloom character: All the genotypes were classified in to four groups of bloom i.e., B0, B1, B2 and B3. Maximum number of genotypes (50) fell in B3 group followed by B1 group (24). Minimum number of genotypes (8) showed almost B0 bloom and B2 represented 18 accessions. Normally, bloom appeared on the stem and lower and upper surface of the leaf named, triple bloom. Stem and its lower surface represented double bloom. Of 100 accessions, 50% genotypes showed the presence of the bloom on upper surface of leaf and stem. Eight genotypes showed no appearance of bloom either on leaf or stem, means B0 bloom. Twenty four genotypes showed bloom on stem and 18 genotypes marked on both stem and leaf. The higher intensity of bloom was observed when the temperature went down very low in winter season. Bloom character was meant to isolate the genotypes based on its intensity.

Spike characters: Genotypes were classified in to three groups namely, compact (8), semi-compact (30) and loose (62). Maximum number of genotypes exhibited loose/lax nature of spike whereas, compact nature was minimum. It obviously showed and observations revealed that loose nature of spike is not highly productive. Compact nature of spike showing compact arrangement of the capsule at raceme may attract high incidence of insect-pests and diseases. Semi-compact nature in castor is preferred more as it provided good scope for hybridization breeding to develop varieties having high yield and high oil content.

Number of nodes is an important character in castor to assess the maturity duration of the crop during selections in breeding programme and in the collection of castor genotypes. Fewer number of nodes are caused to reduce the maturity duration.

In the present study, some genotypes were identified to be promising in yield and other characters were ICC-9801, 7911, KC-1, KC-5, KC-12, KC-65, KC-61, ICC-9810, ICC-9708 and ICC-9825, which could be utilized further in the breeding programme.

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Tissue culture studies in castor, *Ricinus communis* L.

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Abstract

The present investigation has been undertaken to assess the *in vitro* responses of cultured tissues of castor. Regeneration of different explants (cotyledonary leaf, hypocotyls, roots, primary leaf and decoated seed endosperm with embryo) was tested on Murashige and Skoog (MS) basal medium fortified with cytokinins (BA, TDZ, 2ip, Kn) and auxins (NAA, IAA, IBA and 2,4-D) singly and in combination. Green nodular organogenic calli were obtained on MS basal medium fortified with TDZ (0-6.0 mg/l) +NAA (0-1.0 mg/l); BA (0.2-5.0 mg/l) +NAA (0-1.0 mg/l) from primary leaf and cotyledonary leaf respectively. Brownish friable calli were induced on medium with BA (0.2-5.0 mg/l) + 2,4-D (0.1-5.0 mg/l) from cotyledonary leaf and hypocotyls. Somatic embryo like structures were observed in 2,4-D (0.1-5.0 mg/l)+2ip (0.2-10 mg/l) combination from cotyledonary leaf. MS medium with 2,4-D + Kn induced white flaky callus which is non organogenic. White flaky callus also obtained on MS medium with 2,4-D +Kn with different osmoticum (sucrose=3, 6, 9, 12, 15, 18%) from decoated seed embryo as an explant. Very poor response of callus induction was obtained from roots on TDZ, BA with 2,4-D combination. Further investigations are underway for obtaining direct adventitious shoots and callus mediated shoot regeneration in castor.

Keywords: Castor, *in vitro* propagation, organogenic callus, cytokinins, auxins

Introduction

The castor-bean is one of the medicinally important crops, largely cultivated for its industrially valued oil. Castor oil was primarily used for medicinal purposes and as a general industrial lubricant. Castor seed oil and its derivatives have become important commodities and an increasing number of uses are being found for them in the industrial world. The derivatives are used in a range of sectors including agriculture, textile industry, paper industry, plastics engineering, rubber and pharmaceuticals. However despite the high industrial demand, its cultivation poses serious health concerns due to the presence of the ricin toxin (Lord *et al.*, 1994; Hartley and Lord, 2004). Genetic engineering appears to be an effective approach to reduce the levels of these hazardous proteins and to confer resistance to biotic stresses. Therefore, an efficient regeneration protocol of castor needs to be established. Castor is extremely recalcitrant to *in vitro* regeneration. Most of the early studies using vegetative tissues as an explants have proven to be either inefficient or difficult to reproduce (Athma and Reddy 1983; Reddy *et al.*, 1987; Reddy and Bahadur, 1989; Sarvesh *et al.*, 1992; Ahn 2007; Ganesh Kumari *et al.*, 2008). Few studies were reported for whole plant regeneration through meristem based (shoot tip and embryo axes) culture (Sujatha and Reddy 1998; Iftekhar Alam *et al.*, 2010). Owing to difficulties with tissue culture based regeneration protocols, genetic transformation of castor was carried out using meristamatic explants (Sujatha *et al.*, 2005; Malathi *et al.*, 2006; Sailaja *et al.*, 2008 and Sujatha *et al.*, 2009). The transformation efficiency of meristem-based protocols was found to be very low (0.08%). However, and use of meristems leads to chimaeras. Hence, it is therefore proposed to develop a reliable and efficient tissue culture regeneration system as a prelude for development for transgenics in castor.

Materials and methods

Seeds of castor cv. 48-1 (Jwala) were obtained from the seed producing Unit at the Directorate of Oilseeds Research, Hyderabad, India. Mature seeds were decoated and rinsed in running tap water for 30 min. The decoated seeds were surface sterilized with 0.1% (w/v) aqueous mercuric chloride solution for 12 min and subsequently rinsed 3 times with sterile distilled water and a final wash was carried out for 5 min with an antibacterial agent streptomycin (1 mg/ml in sterile water). The material was blotted dry on sterile filter paper and germinated on half-strength MS basal salt media (Murashige and Skoog, 1962) with 1.5% sucrose, pH 5.8 and gelled with 0.8% agar (Hi-media, Mumbai, India). The seedling explants used, *viz.*, root , hypocotyl, cotyledonary leaf from *in vitro* as well as from vermiculite, whole seed endosperm, primary leaf from seedlings raised in pots, young leaf from field grown plants.

Direct shoot induction and callus mediated shoot regeneration was assessed on MS basal medium fortified with 400 combinations and concentrations of cytokinins and auxins which includes 6-Benzyladenine (BA) (0.2-5.0 mg/l), Thidiazuron (TDZ) (0.1-6.0 mg/l), Kinetin (Kn) (0.5-5.0 mg/l), N6-[2-Isopentenyl]adenine (2ip) (0.2-10.0 mg/l), with Naphthaleneacetic acid (NAA) (0-1.0 mg/l), Indole-3-acetic acid (IAA) (0.1-1.0 mg/l), Indole-3-butyric acid(IBA) (0.2-1.0mg/L); 2,4-Dichlorophenoxyacetic acid (2,4-D) (0.1-5.0 mg/l), and also tested with different sucrose concentrations (3-18%). Cultures on MS medium fortified with different levels 2, 4-D (0.2-15 mg/l) were incubated in dark for direct somatic embryogenesis. The cultures were incubated at 27±1°C under a 16/8 h photoperiod provided by cool fluorescent lights at intensity of 30 μmol/m^2/s.

Results and discussion

The aseptically cultured seeds were exhibited 95% germination after 6-10 days of inoculation on half-strength MS basal salt media. When different types of explants were compared in terms of callus induction with above combinations, cotyledonary leaf and primary leaf showed best callus induction after 25 days of culture while hypocotyls and roots showed poor callus induction after 25-30 days of culture. Out of 400 different types of growth regulator combinations, BA (0.2-5.0 mg/l) +NAA (0-1.0 mg/l) favoured formation of green nodular callus from cotyledonary leaf. Medium with TDZ (0-6.0 mg/l) +NAA (0-1.0 mg/l) showed green nodular, brownish nodular, yellowish compact calli from primary leaf (obtained from 10 day old seedlings raised in pots) after 25 days of culture. Somatic embryo and shoot like structures were observed on medium supplemented with 2,4-D (0.1-1.0 mg/l)+2ip (0.2-5.0 mg/l); BA (0.2-5.0 mg/l)+2,4-D (0.1-5.0 mg/l) combinations but most of the calli were turned brown on BA with 2,4-D combination after 25 days of culture. White flaky callus was observed from whole endosperm with embryo on MS basal medium fortified with 2, 4-D and Kn with 3% and 6% sucrose concentration. The effect of orientation of cotyledon explant (adaxial vs abaxial) on callus formation and shoot regeneration were investigated. Cotyledonary leaf explants when placed with adaxial side touching medium surface showed greater response as compared to abaxial side touching the medium. The callus response from *in vitro* seedlings is superior than seedlings from vermiculite. Explants derived from young seedlings (8 day old) possessed better regenerative potential when compared to older seedlings (10 to 20 day old).

Callus induction from cotyledonary leaf and hypocotyls showed greater response in light than in dark on MS medium fortified with different levels of 2, 4-D (0.2-15 mg/l), in dark most of the cultures produced white flaky callus which was non organogenic. Thus, in terms of regenerative potential cotyledonary leaf and primary leaf showed superiority for callus induction followed by hypocotyls and roots. Further, investigations are underway for obtaining adventitious shoots through direct and callus mediated regeneration.

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Molecular markers and marker assisted breeding in castor : Current status and future prospects

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Abstract

Studies based on morphological parameters and biochemical markers like isozymes and total seed protein profiles did not reveal the variability among castor genotypes effectively. The current status of use of different molecular markers in understanding the genetic relationships in castor is briefly reviewed. Development of Expressed sequence tag simple sequence repeat (EST-SSR) markers from the enormous complementary DNA sequence data available in the public database is advocated. The genomic SSRs and EST SSRs generated in related species like Hevea, Jatropha and Cassava can be tried in castor owing to their transferability. The need for development of appropriate mapping populations for linkage map construction and establishing marker trait linkages for practising marker assisted selection in castor is emphasised.

Keywords: Single nucleotide polymorphism, homoplasy, microsatellites, ESTs, linkage maps

Introduction

Castor (*Ricinus communis* L., 2n=2X=20, Euphorbiaceae), is an industrially important non-edible oilseed crop widely cultivated in the arid, semi-arid and the temperate regions of the world. India is the leading producer of castor in the world with an annual production of about 0.73 Mt which accounts for nearly 60% of the world's production. The seed contains more than 45% oil and is rich in a hydroxy fattyacid, ricinoleic acid (80-90%). Owing to its unique chemical and physical properties, castor oil is used as a raw material for numerous and varied industrial applications including manufacture of polymers, coatings, lubricants for air crafts, cosmetics, etc., and for production of biodiesel. The significance of castor in recent years has increased as it brings in a sizeable amount of foreign exchange to the country.

Efforts have been concerted world wide in preserving and exploiting the available limited genetic diversity for crop improvement programmes. Four centers of genetic variability were observed for castor *viz.*, Irano-Afghanistan-USSR region, Palestine-SW Asia, India-China and the Arabian Peninsula, each with its own specific plant characteristics supporting its polyphyletic origin (Moshkin, 1986). The USDA-ARS plant genetic resource conservation unit (Griffin, GA, USA) maintains 1,043 diverse worldwide accessions of castor as *ex-situ* collections. Attempts were made to collect, conserve and study the variability of castor from different parts of India (Anjani *et al.*, 1994; 1999).

Genetic diversity

An understanding of the extent of genetic diversity in the germplasm is critical for the success of breeding programmes. Traditional methods using morphological characteristics for establishment of genetic relationships among castor genotypes were largely unsuccessful due to the strong influence of environment. Various biochemical markers including isozymes have been employed to determine the genetic relatedness of Ricinus with the related species Jatropha (Sathaiah and Reddy, 1984; 1985). Peroxidase and esterase activities and seed protein profiles were used to differentiate tall and dwarf varieties, for hybridity confirmation of F_1s and to predict positive heterobeltiosis for seed yield in castor. Total seed storage protein profiles based on SDS- PAGE revealed very limited intraspecific variability between castor genotypes belonging to different geographical regions (Cheema *et al.*, 2010). Selection based on genetic information using neutral molecular markers is essential, as it is more reliable and consistent. The importance of molecular markers in accurate assessment of genetic diversity has been realized and during the past 2 to 3 years various molecular markers have been employed for determining the extent of genetic diversity in castor. Randomly amplified polymorphic DNAs revealed greater polymorphism (80.2%) when compared to Inter Simple Sequence repeats (68%) in a set of 22 castor genotypes (Gajera *et al.*, 2010). Tanya *et al.* (2010) reported a genetic distance of 60-72% between castor and different species of *Jatropha* using ISSRs. A study on a worldwide castor germplasm collection representing 35 countries of five continents using Amplified fragment length polymorphic and SSR markers revealed lower genetic diversity values (He=0.126) with AFLPs when compared to SSR markers (He=0.188) (Allan *et al.*, 2008).

Genomics

Genome sequencing of castor has been initiated at the Institute for Genomic Research (TIGR) and the genome size was estimated to be ~ 400 Mb consisting of 25,828 contigs. The genome has been assembled and sequenced to 4.6 X coverage using a whole genome shotgun strategy (Chan *et al.*, 2010). A total of 1,32,839 nucleotide sequences, 63,388 expressed sequence tags and 63,072 protein sequences have been deposited in the public database. The other related species in the family *Euphorbiaceae* are also being sequenced to various levels and a lot of sequence information in Cassava (81,010 ESTs and 1328 nucleotide sequences), Hevea (13,016ESTs, 1842 nucleotide sequences) and Jatropha (26,446 ESTs, 749 nucleotide sequences) is available in the public database. These sequences offer a valuable resource for development of genic microsatellites and EST-SSRs. Microsatellites or Simple Sequence Repeats (SSRs) are one of the most widely used molecular markers in plant breeding, agricultural genetics, mapping, marker assisted selection, and genetic diversity studies. Genomic SSRs in castor represent a moderate level of genetic diversity and the SSR loci in the untranslated regions are found to be more polymorphic than those in the exons (Bajay *et al.*, 2009). SSR markers in castor were relatively limited because their denovo development is expensive, laborious and time consuming. But with the availability of enormous sequence data from the public databases and with the advent of bioinformatics tools, it has become cost effective and fast approach to scan for microsatellite markers. However size homoplasy is often a concern (Estoup *et al.*, 2002).

Cross-genera transferability

Expressed sequence tag databases have been proven to be a valuable source of polymorphic SSRs in a number of plant species and owing to their evolutionally conserved nature are known to show a high degree of transferability. Recent studies showed that the transfer efficiency of EST-SSRs was higher than that of genomic SSRs in cross-species/genera (Aggarwal *et al.*, 2007). Recently, single nucleotide polymorphisms have emerged as an increasingly valuable marker system for assessing population genetic structure in castor. Their higher evolutionary conserved nature makes them less subject to homoplasy. With the advent of novel and relatively cheaper sequencing technologies they have gained greater utility in recent times. Genome wide assessment of genetic diversity in castor using SNPs revealed low genetic diversity (Foster *et al.*, 2010). The possibility of transferring EST-SNPs from barley to other cereal species has been demonstrated indicating their transferability across species (Kota *et al.*, 2001).

Inspite of the availability of several molecular markers like RAPD, ISSR, AFLP, Genomic SSRs and EST-SSRs efforts on development of a linkage map in castor are lacking. Appropriate segregating populations generated from crosses with relatively distant parents is a prerequisite for linkage map construction. Development of F_2 populations is relatively easy and takes less time while recombinant inbred lines (RILs) and near isogenic lines (NILs) take 6 to 7 seasons through single seed descent method and backcrossing respectively. Backcross populations are essential in crosses where the donor is agronomically very inferior and two to three rounds of backcrossing is done to recover the genome of the recurrent parent. Recently a linkage map was constructed in Cassava in the family Euphorbiaceae from EST and genomic SSRs (Kunkeaw *et al.*, 2010). Genomic SSRs owing to their highly polymorphic nature and EST-SSRs owing to their availability in large numbers are the markers of choice for constructing framework linkage maps, marker assisted selection and introgression of traits of interest in castor. The EST-SSRs developed from the related species Hevea (90%) and Cassava (15.3%) had greater transferability rates (Feng *et al.*, 2009; Raji *et al.*, 2009) in castor and thus offer a great potential for their use in marker assisted breeding programmes in castor. Efforts to identify linkage of molecular markers with traits of interest are lacking in castor in order to practise marker assisted selection. Several sources of resistance to major diseases of castor were identified and their genetics being predicted to be under monogenic/oligogenic control (Anjani *et al.*, 2004). Such donors may be crossed to elite varieties to generate appropriate segregating populations to map the resistance genes involved with the available set of genomic and EST-SSRs. Conversely foreground selection can be practiced with the donor parent alleles of the linked markers, background and recombinant selection with the recipient parent alleles of the unlinked polymorphic markers for introgressing the genes of interest with least linkage drag. Once saturated genetic linkage maps are constructed, and marker trait linkages established, marker assisted introgression of important traits and map based cloning of the genes involved can be practised with great success in castor.

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Canonical correlation analysis for determination of interrelationships between root and shoot characters in castor

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Abstract

In this study, canonical correlation analysis has been used to understand the relationship between and among shoot and root characters. The study revealed that shoot dry weight and stem weight followed by stem girth and plant height are the important variables contributing towards the root characters. And among the root characters, root dry weight and root volume are the important characters which influence more on shoot characters.

Keywords : Canonical correlation, root characters, shoot characters

Castor crop frequently grown in marginal and sub marginal shallow soils under rainfed conditions with low inputs. As it is considered as drought tolerant, limited attempts were made so far to identify genotypes that perform well under rainfed conditions. With the prediction of extreme events due to climate change, world over now there is more emphasis on breeding varieties and hybrids that tolerate drought. Earlier studies indicated that variations do exist among the genotypes for their drought tolerance.

Among the several factors contributing for drought tolerance, root characters play crucial role in the mechanism of dehydration postponement since they govern the plant growth, extraction of water and nutrients from deeper layers of the soil. Plants with large root system could thus maintain a high rate of water uptake from the soil when faced with depleted water potential. This in turn influence the performance of the shoot growth and have a bearing on yield potential. This implies there exists a strong association between root and shoot characters. Knowledge about these complex interrelationships is essential to understand the underlying root characters responsible for drought tolerance. The complexities of these interrelationships are not exploited so far. Simple correlations are inadequate to address these complexities existed between shoot and root characters, as root and shoot characters are neither independent from each other nor among themselves. Therefore one has to consider the correlation between these sets of variables simultaneously. Canonical correlation, a well-known multivariate technique, measures complex relationship between two sets of interrelated variables. It is also concerned with two sets of variables related to each other and with how much variance of one set is common with or predictable for the other set (Weiss. 1972, Akbas and Takma, 2005, Mahmoud Toorchi *et al.*, 2006). Canonical correlation analysis model that facilitates the study of linear interrelationships between a set of independent variables and a set of dependent variables. Canonical correlation analysis develops a canonical function that maximizes correlation coefficients between the two canonical variates. Each canonical variates is interpreted with canonical loadings/ structural canonical correlations with their individual variables and canonical cross loadings with the other set of variables. A detailed description and computational procedure for the canonical analysis can be obtained from Johnson and Wichern (2002). Thus, in the present study an attempt has been made to find the strength of association between root and shoot characters.

Materials and methods

An experiment with 67 castor genotypes is conducted in randomized block design with two replicates in specially constructed structures during rainy season, 2009. Observations on 5 shoot traits *viz.*, plant height (cm) (PH), stem girth (cm) (SG), leaf area index (LAI),) stem weight (g) (STW) and shoot dry weight (g) (SDW) are considered as shoot variables root length (cm) (RL), root volume (RV), root dry weight (RDW) , root density (RD) and root to shoot ratio (RS) are considered as root variables to study the interrelationships between the root and shoot characters.

The data based on mean over replications were subjected to simple and canonical correlation analysis using PROC CORR AND PROC CANCORR procedures in SAS 9.2 ver. Statistical software.

Results and discussion

The preliminary analysis of the data revealed that the data contains wide variation and there exists high simple correlations among the shoot and root characters. Although there are high correlations among and between the characters it would be more informative instead of interpreting many simple correlations among variables if the linear function of the correlated variable of the two sets are considered. This would enhance the interpretation of results since the characters themselves are correlated. Hence, canonical correlation analysis was computed.

Wilk's Lambda showed 0.015 ($p<0.01$) indicates the presence of non-zero canonical correlations and there exists the linear relationship between shoot and root characters. The first canonical function shows a canonical correlation coefficient of 0.98 and second canonical function is with 0.78 canonical correlation. The likelihood ratios for first two canonical variates 0.15 and 0.89, respectively are significant ($P<0.01$) and the rest of the three canonical variates are not significant. This implies that the linear functions of the root characters and shoot characters have strong association and 99.5% of the variability explained by the first two canonical functions. Thus, only first two canonical variates are described in the present study. Since canonical loadings/structural canonical correlations are helpful in identifying and their contributions to the canonical variate they are presented in table 1. These inter-set structured correlations give the magnitude and direction of relationship between individual variables to the canonical variate. A perusal of the table 1 shows that all the shoot variables are having high correlations ranging from 0.78 to 0.98 with Shoot1 canonical variate and Shoot 2 canonical variate is mostly influenced by pH (0.48) and SG (0.38) and there is week negative correlation with LAI and SDW. Similarly Root1 is most influenced by RDW (0.91) and RV(0.88) and RS and RL have highest structural correlations with Root2.

There are two types of contributions that define the relationship between the two variable domains. One is the liner function of root characters i.e., root canonical variates and their importance in the expression of individual shoot characters and the other is individual contribution of root characters on the expression of the shoot characters and vice versa. The contribution of all the root characters to the expression of SDW is 92% by the Root1 canonical variate and 94% from the first two root canonical variates. This was followed by a contribution 87% for the STW and 72% for the plant height. Similarly, the contribution of shoot characters to the expression of 88% for RDW and 87% for the RV (Table 2).

Table 1 Canonical loadings and cross canonical loadings for shoot and root characteristics

Shoot variable	Shoot1	Shoot2	Root1	Root2
PH	0.78	0.48	0.76	0.37
SG	0.81	0.38	0.79	0.29
LAI	0.80	-0.02	0.78	-0.02
STW	0.95	0.08	0.93	0.06
SDW	0.98	-0.16	0.96	-0.12
Root variable	**Root1**	**Root2**	**Shoot1**	**Shoot2**
RL	0.30	0.58	0.29	0.45
RV	0.88	0.46	0.86	0.36
RD	-0.12	-0.13	-0.11	-0.10
RDW	0.91	0.37	0.89	0.29
RS	-0.01	0.94	-0.01	0.73

Shoot 1 and 2 are shoot canonical variates; Root 1 and 2 are root canonical variates

The cumulative redundancy measures for a given set of variables gives the average squared multiple correlation which explains the amount of total variability in one domain accounted by other domain. The result showed that 78% variance in the shoot characters explained by the root variates and 52% of the total variance in the root characters explained by the root characters. Based on the interrelationships existing in the shoot and root characters it can be concluded that shoot dry weight and stem dry weight are the important characters for prediction of root characters and root dry weight and root volume are for predicting the shoot characters.

Table 2 Cumulative proportion variance of characters contributing to their opposite canonical variates and cumulative redundancy

Shoot character	Root1	Root2	Root Character	Shoot1	Shoot2
PH	0.58	0.72	RL	0.09	0.29
SG	0.62	0.71	RV	0.75	0.87
LAI	0.61	0.61	RD	0.01	0.02
STW	0.86	0.87	RDW	0.80	0.88
SDW	0.92	0.94	RS	0.00	0.53
Cumulative redundancy	0.72	0.78	Cumulative redundancy	0.32	0.52

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Screening of castor (*Ricinus communis* L.) genotypes using EST-SSR markers

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Abstract

Genetic diversity among parents is essential since the crossing programme involving genetically diverse parents is likely to produce high heterotic effects and also more variability could be expected in the segregating generations. In the present investigation, genetic diversity of 15 castor genotypes using EST-SSRs was studied. All the castor genotypes showed polymorphism with the EST-SSR primers tested with mean (2.83) number of alleles per locus. Cluster analysis using UPGMA showed that castor genotypes grouped into three major groups with the correlation coefficient ranged from 0.50 to 0.94.

Keywords: Castor, EST-SSRs, genetic diversity, marker

Introduction

Ricinus communis L. (2n = 2x = 20), commonly known as castor, is one of the most important non-edible oil seed crops that are widely grown in India, China and Brazil. The castor seeds are primarily used in industry, farming and medicine. Heterosis levels in castor hybrids are not up to the desired level due to narrow range of diversity between male and female lines and development of parental from few common sources (Lavanya *et al.*, 2006). Genetic diversity among parents is essential since the crossing programme involving genetically diverse parents is likely to produce high heterotic effects and also more variability could be expected in the segregating generations. The present study was carried out to know the genetic diversity of castor genotypes using EST-SSRs.

Materials and methods

Plant material and DNA extraction: Genomic DNA was extracted from bulk sampling of minimum of 10 individual plants for each genotypes, following the procedure described by Doyle and Doyle (1990) with minor modifications.

EST-SSR analysis: Six EST-SSR primers developed in the Directorate of Oilseeds Research (data not published) were used for screening 15 castor genotypes. The reactions were performed in a total volume of 20μl reaction volume containing 2.0μl 10×assay buffer containing 1.5mM $MgCl_2$ (Bangalore Genei, India), 0.08 mM dNTPs (Bangalore Genei, India), 5pm of each forward and reverse primer, 1.0U *Taq* DNA polymerase (Bangalore Genei) and 25 ng template DNA. The PCR reaction was programmed as follows: denaturation at 94°C for 5 min followed by 30 cycles of denaturation at 92°C for 30 sec, primer annealing at 56°C for 30 sec and primer extension at 72°C for 30 sec. The last cycle was followed by final extension at 72°C for 6 min. PCR products were kept at 4°C and the amplifications were repeated twice to confirm the results. The samples were electrophoresed in 6% denaturing polyacrylamide sequencing gel on a Sequi-Gen (BioRad, USA) for 2 h in 1X TBE at 100W, 50 mA at 55°C. The PAGE gels were dried completely and photographed using digital camera.

Data analysis: Amplification products were scored for the presence (1) or absence (0) of bands and binary matrices were assembled for the EST-SSR markers. The binary matrices were subjected to statistical analyses using NTSYS. The similarity matrices were deduced and dendrogram was constructed by applying unweighted pair group method with arithmetic mean (UPGMA) clustering algorithm. For individual primer, number of polymorphic bands (n), percentage polymorphism (p), number of banding patterns (N), polymorphic information content (PIC) was calculated according to Anderson *et al.* (1993).

Results and discussion

All the loci (100%) were polymorphic. A total of 17 polymorphic alleles were detected and the number of alleles detected on a single locus ranged from 2 to 3, with an average of 2.83 alleles per locus. The molecular size of the alleles ranged from 145 to 292 bp and allelic frequencies ranged from 0.13 to 0.60. The PIC of EST-SSR primers tested ranged from 0.48 to 0.64 with a mean of 0.57. Cluster analysis showed that castor genotypes grouped into three major groups. The correlation coefficient ranged from 0.50 to 0.94 (Fig. 1). The genetic variation among the castor genotypes is low in the studies with EST-SSRs, which is similar to the results of Foster *et al.* (2010) and Allan *et al.* (2008). In world wide genotyping of castor germplasm from different geographical areas by Foster *et al.* (2010), no unique alleles in any of the accessions across different regions are found, which is consistent with a domesticated species in which genetic variation, has been reduced. Allan *et al.* (2008) also found similar results; the nine SSR loci showed the average number of alleles per locus, 2.4 and found limited genetic diversity and structure for populations in genome wide diversity studies in castor. The lower PIC of EST-SSRs relative to genomic SSRs is perhaps due to higher conservation of coding regions among the genotypes within a species (Eujayl *et al.*, 2002). In spite of the higher polymorphism, genomic SSRs could not reflect agronomic differences in the genetic resource evaluation, which could be explained by the fact that all genomic SSR markers were not found in the transcribed regions (Li *et al.*, 2006). Therefore, EST-SSRs would be more efficient for evaluating the polymorphism, differentiation, phylogenetic relationship and population structure and genetic resources. Genetic diversity in castor germplasm found relatively low as compared to levels of genetic diversity found in different plant studies (Nybom, 2004). Low levels of genetic diversity in castor are consistent with comparable reduced variation in many cultivates species, such as soybean (Hyten *et al.*, 2006) and wheat (Hilu, 1994).

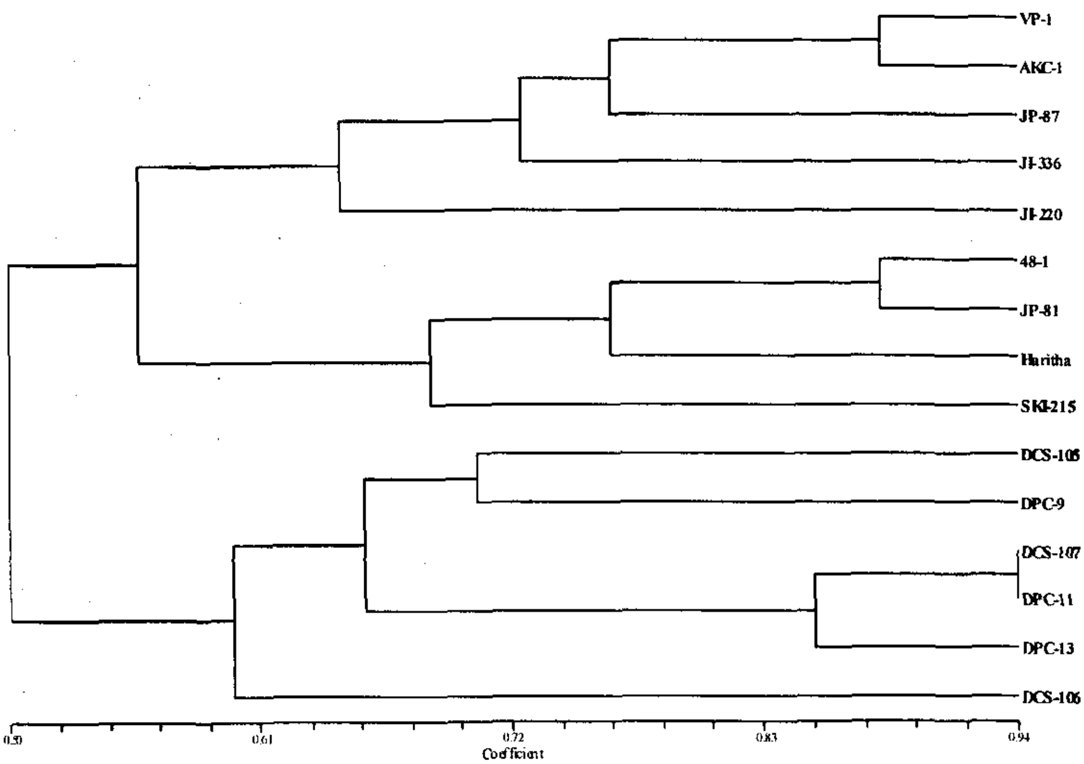

Fig. 1. Dendrogram of castor genotypes using EST-SSR data

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Simultaneous selection index for yield and stability for selecting castor genotypes

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Abstract

The additive main effects and multiplicative interaction (AMMI) model was performed to develop the yield stability index for 12 castor genotypes grown in 19 locations during 2007-08. Combined analysis of variance showed highly significant ($p<0.01$) genotype environment interaction effect indicating that possibility of selection of stable genotypes. The results of AMMI analysis showed that 87 % of the total Sum of squares was contributed by environmental effects. It indicated that the environments were diverse and causing most of the variation in the grain yield. According to mean yield the genotypes RHC-199, NBCH-2007-2 can be selected, whereas genotypes NBCH-2007-2, JHB-958, SHB-849, Sagarsidhi and RHC-199 can be selected based on simultaneous selection index.

Keywords: Castor, yield stability index, AMMI model

Introduction

In multi-location trials assessment of cultivar performance is difficult because of the presence of significant genotype x environment interaction. Presence of such interaction can reduce progress from selection. A universally acceptable selection criterion that takes G x E interaction in to consideration does not exist. Whenever an interaction is significant, the use of main effects (overall genotypes means across environments) is questionable.

Hence stability of performance should be considered as an important aspect of yield trials. There is need of statistic that provides a reliable measure of stability or consistency of performance across a range of environments. However, the stability measure alone is of limited use. For a successful breeding or cultivar testing programme, both stability and yield must be considered simultaneously. Kang (1993) developed yield stability statistic for selection of varieties. But this method has one disadvantage that it has biased towards yield performance. Rao *et al.* (2007) proposed an simultaneous index by utilizing the information on cultivar yield and cultivar contribution to pooled MS(Y/L).

The additive main effects and multiplicative interaction (AMMI) model is a powerful tool for multi-environmental trials. Zobel *et al.* (1988) first used the AMMI model in the analysis of yield trials. This is also called as FANOVA. It includes both additive and multiplicative components in to an integrated least square analysis (Mohammadi *et al.*, 2007). The present research was carried out to quantify interaction effect on yield and to develop index for determining stable entries with high yielding performance.

Materials and methods

This study was carried out with 12 castor genotypes with GCH-5, DCH-177 and GCH-4 as standard checks at 19 locations in winter season of 2007. The experimental layout at each location was randomized block design with three replications. Combined analysis of variance and mean comparison was done using MSTAT-C and bartletts test was done for homogeneity of error variance using SPSS software. AMMI analysis was carried out using following model suggested by Crossa *et al.* (1991).

$$Y_{ij} = \mu + g_i + e_j + \sum_{n=1} \lambda_n \alpha_{in} \gamma_{jn} + \theta_{ij}$$

where, Y_{ij} is the yield of I th cultivar in j th location, μ is General mean, g_i is Ith genotypic effect, e_j is jth location effect, λ_n are given values of PCA axis n, α_{in} and γ_{jn} are the Ith genotype and jth environment PCA scores for the PCA axis n and n' are no of PCA axis retained in the model. AMMI stability value (ASV) (Purchase, 1997) will be calculated based on PCA1 and PCA2 scores for each genotype. The larger the PCA score, the more specifically adapted to certain environments. Simultaneous selection index for each genotype was calculated based on mean yield rank across environments and rank of AMMI stability value which incorporates both maen yield and stability index in single criteria.

Results and discussion

Combined analysis of variance showed highly significant genotype environment interaction effect. It indicates that the effect of environment on genotypic effect. The ranking of genotypes based on Duncan's multiple range test revealed that the top rank goes to RHC-199 genotype and minimum seed yield belonged to genotype NBCH-207-1. As interaction effect showed significant effect, we can further proceed to AMMI analysis. In AMMI analysis the yield sum of squares was partitioned in to genotype, environment and their interaction. The interaction effect is further partitioned in to principal components. The results of AMMI analysis showed that 87% of the total sum of squares was contributed by environmental effects. It indicated that the environments were diverse and causing most of the variation in the grain yield. The first PC captured 32.4% and PC2 captured 21.9% of interaction effect. The mean squares for both principal components were significant. These results indicated that AMMI model fits the data well. Genotype with least ASV score is most stable genotype. The ranks based on mean grain yield and genotypic stability index were presented in table1. The least index is considered as most stable genotype with high yield. According to mean yield the genotypes RHC-199, NBCH-2007-2 can be selected, where as genotypes NBCH-2007-2, JHB-958, SHB-849, Sagarsidhi and RHC-199 can be selected based on simultaneous selection index. Therefore for the selection of stable and high yielding genotypes, simultaneous selection index can be used and make use of effect of genotype and environment interaction.

Table 1 Genotypic stability index and mean grain yield of castor genotypes

Genotype	Yield(kg/ha) (kg/ha)	Yield rank	GSI	GSI rank
DCH-177 ©	1829	7	13	6
SHB-849	1863	4	7	3
RHC-270	1712	9	19	10
GCH-5 ©	1881	3	14	7
Sagar Sidhi	1833	6	10	4
JHB-958	1855	5	6	2
NBCH-2007-1	1667	12	20	12
SHB 846	1676	10	19	11
RHC-199	1947	1	13	5
GCH-4 ©	1729	8	15	8
SHB-834	1670	11	16	9
NBCH-2007-2	1902	2	4	1

C = Standard check

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Approaches of indirect selections for quantitative traits in castor, *Ricinus communis* L.

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Abstract

A set of 15 castor accessions was used to study the correlation coefficient and direct and indirect effects of path coefficients to study the effect of characters for improvement in yield. It was observed that genotypic were higher than the phenotypic correlation coefficients. Seed yield exhibited significant positive association with number of nodes to primary spike, number of spikes/plant and 100 seed weight. Path analysis revealed that 100 seed weight recorded maximum direct effect on seed yield followed by number of spikes/plant and number of nodes on seed yield.

Keywords: Castor, correlation and path analysis

Introduction

Before initiating any breeding program, it is essential to obtain information regarding the interrelationship between various yield attributing characters with seed yield. A knowledge of association between yield and yield components will serve to make simultaneous selection for more characters. Castor as a non-edible oilseed crop plays an important role in Indian economy. The crop is grown for its non edible oil which is completely biodegradable with its utilization in several fields such as manufacturing lubricants, providing inks, pharmaceuticals, etc. To develop elite genotypes, knowledge on inter relationship among yield and its component characters and direct and indirect contribution towards yield is important. Hence, the present study was undertaken to derive information on phenotypic, genotypic correlation, direct and indirect effects of yield components in castor genotypes.

Materials and methods

Fifteen genotypes were evaluated in a randomized block design with three replications at Oilseeds Research Station, Tindivanam under rainfed conditions of 2007 -08. Each genotype was raised Observations were recorded on five randomly selected plants in each genotype/replication for the traits *viz.*, days to 50% flowering, plant height (cm), number of nodes to primary spike, number of spikes, 100 seed weight (g)and seed yield. The genotypic and phenotypic correlations coefficients (Singh and Chaudhary, 1979) and path analysis (Dewey and Lu, 1959) were computed.

Results and discussion

Analysis of variance revealed that all the entries were significantly different for the characters studied. The genotypic correlations were higher than their corresponding phenotypic correlations which may be due to the modifying effect of environment on association of characters at genetic level (Table 1).

Table 1 Genotypic (G) and phenotypic (P) correlation coefficients between different traits of 15 castor genotypes

Traits		Days to 50% flowering	Plant height	Number of nodes to primary spike	Number of spikes	100 seed weight	Seed yield
Days to 50% flowering	G	1.0	0.615**	0.696**	-1.017**	-0.433*	-12.89**
	P	1.0	0.168	0.098	-0.458*	0.022	-0.122
Plant height	G		1.0	0.985**	-0.401*	0.340	-1.87**
	P		1.0	0.581**	-0.260	0.080	0.046
Number of nodes to primary spike	G			1.0	-0.599*	0.073	2.18**
	P			1.0	-0.451*	0.054	0.022
Number of spikes	G				1.0	0.171	3.35**
	P				1.0	0.145	-0.274
100 seed weight	G					1.0	3.51**
	P					1.0	0.271

*, ** Significant at P = 0.05 and P 0.01 level, respectively

Seed yield had highly significant and positive association with number of nodes, number of spikes/plant and 100 seed weight but negative association with plant height and days to 50% flowering. This reveals the importance of number of nodes, spikes and 100 seed weight in increasing the seed yield. Similar results were obtained by Mehata and Vashil (1998). The highest degree of association between 100 seed weight and seed yield was the most reliable component of yield and could be very well utilized as an indicator of yield. The earlier studies also indicated the importance of 100 seed weight as one of the important yield component (Mehata and Vashil, 1998 and Bhat and Reddy, 1981). Plant height and number of nodes showed significant and positive inter correlations among themselves. Days to 50% flowering had significant negative association with 100 seed weight, number of nodes, number of spikes/plant. Number of spikes had significant negative association with number of nodes and plant height.

The path coefficient analysis on genotypic correlation of seed yield is given in table 2. The direct effect was high and positive for 100 seed weight, number of spikes followed by number of nodes. The indirect effect of 100 seed weight through 100 seed weight, number of spikes, number of nodes and plant height were positive. These results are in conformity with by Mehata and Vashil (1998). In this study residual effect was low indicating adequate characters were utilized for the study. It could be inferred that reliance on 100 seed weight followed by number of spikes/plant and number of nodes will result in improvement of seed yield in castor.

Table 2 Direct and indirect effects of different traits on seed yield

Traits	Effect *via*					
	Days to 50% flowering	Plant height	Number of nodes	Number of spikes	100 seed weight	Seed yield
Days to 50% flowering	0.355	-1.151	0.715	-1.074	:0.541	-12.89**
Plant height	0.218	-1.872	1.010	-0.424	0.425	-1.87**
Number of nodes	0.247	-1.843	1.026	-0.633	0.092	2.18**
Number of spikes	-0.361	0.751	-0.615	1.055	0.215	3.35**
100 seed weight	-0.153	-0636	0.075	0.181	1.251	3.51**

Residual effect = 0.72 Diagonal values denote direct effect.

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Pistillate castor DPC-9 : Stability and problems in seed production

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Abstract

DPC 9, the female parent of the castor hybrid DCH-177, was grown for the production of breeder and foundation seed of the pistillate line and for the production of certified hybrid seeds of DCH 177 at various locations during summer and winter season respectively, during 2007-08, 2008-09 and 2009-10. Observations on sex expressions were recorded at suitable intervals to rogue out the off-types The results showed that though the pistillate character is influenced by weather parameters, high level of nutrition and regular irrigation could help to avoid stress and maintain pistillateness in the female lines. Even under unfavourable weather situations, it would be possible to produce seeds with adequate genetic purity. The various implications of sex reversal in pistillate lines in seed production plots on the purity of seed produced is discussed.

Keywords: Pistillate, sex expression, weather, seed production, genetic purity

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop grown in varied agro-climatic conditions for oil, which is suitable for industrial uses especially in lubricants, detergents, wax etc. Castor is sexually polymorphic with different sex forms *viz.*, monoecious bearing staminate flowers at base and pistillate flowers at the top of the raceme, only pistillate flowers along with raceme, pistillate with interspersed staminate flowers (ISF), sex reversals etc. Sex expression in castor is known to be highly influenced by environmental factors (Ramachandram and Ranga Rao, 1988). Seed yield in castor is influenced by several factors out of which sex expression i.e., % pistillateness is very important.

The identification of pistillate line VP-1 led to the development of castor hybrids in India. GCH 4 castor hybrid using VP 1 pistillate line was released for rainfed and irrigated conditions of castor growing areas in the country. Subsequently, researchers developed a number of other pistillate lines *viz.*, Geetha, DPC-9, JP-65, M-574 and SKP-84 and several hybrids suited to varied growing situations have been released. However, sensitivity to the changing environment and various stresses due to improper crop management limits their use in hybrid seed production programmes. Directorate of Oilseeds

Research, Hyderabad had released promising hybrids, DCH 32, DCH 177 and DCH 519 of which DCH 177 is very popular among the farmers of Andhra Pradesh. The pistillate line, DPC 9 which is the female parent of the said hybrid showed varied expressions of sex when grown in different locations and seasons for hybrid seed production as well as pistillate line multiplication. This paper discusses the stability and problems in using DPC 9 in seed production.

Materials and methods

The castor pistillate line DPC 9 (VP 1 x REC 128-1) was developed at the Directorate of Oilseeds Research, Hyderabad and is the female parent of DCH 177 castor hybrid. The pistillate character in DPC 9 was derived from VP-1 which is a 'S' type pistillate line having different sex patterns like: - monoecious, pistillate, pistillate with ISF and early/late revertants. The pistillate line DPC 9 is being maintained from nucleus seed through interspersed staminate flowers (ISF) under summer environment to produce 95 to 100% pistillate plants in the foundation and certified hybrid seed production. The certified seeds/foundation seed of the pistillate line is used in the hybrid seed production plots under winter environment favouring pistillate expression. DPC 9 (female) was sown for the production of breeder and foundation seed of the pistillate line at various locations like DOR farm Narkhuda, DOR-ICRISAT farm, Patancheru, Directorate of Medicinal and Aromatic Plants (DMAP), Anand, Anand Agricultural University (AAU), Anand and Directorate of Sorghum Research (DSR), Hyderabad. For the production of certified hybrid seeds of DCH 177, the female line (DPC 9) was sown at farmer's fields of Mahaboobnagar district of Andhra Pradesh and DOR-ICRISAT farm, Patancheru during summer season and winter season, respectively, during 2007-08, 2008-09 and 2009-10. Observations on sex expression were recorded at suitable intervals to rogue out the off-types and the results are discussed below.

Results and discussions

During 2007-08, DPC 9 was sown at DOR farm, Narkhuda in the month of January 2008 for breeder seed production and it was observed to produce interspersed staminate flowers (ISF) from primary spike itself till later order spikes. In this case, no monoecious and high ISF type plants were found and the interspersed staminate flower induction was quite normal to produce adequate seeds in female plants in seed production plots. But at DMAP, Anand where the foundation seed production of DPC 9 was taken up during January 2008, the ISF production was insufficient to pollinate the female flowers in primary to tertiary order spikes resulting in very poor seed set. Though the temperature and other weather parameters were favourable for ISF production, it was felt that change in agronomic schedules like irrigation and fertigation would cause the kind of stress required for triggering of sex variations like ISF. Hence, adequate ISF production was observed in the later order spikes and the produced pollen was sufficient to pollinate female flowers in those orders, ultimately resulting in average seed set under moderate climate and nutrient management.

Similarly during 2008-09, in the hybrid seed production plots of DCH 177, DPC 9 expressed complete pistillateness when sown in October, 2008 at DMAP, Anand. The frequency of plants with ISF was less to negligible since the crop was raised under irrigated and good nutrient management conditions. The crop sown at DOR-ICRISAT farm in January, 2009 showed good percentage of ISF in the foundation seed crop of DPC 9 which had undergone mild moisture stress leading to good seed set. Interestingly, DPC 9 sown during Oct/Nov, 2009 for hybrid seed production of DCH 177 showed high frequency of plants producing ISF and monoecism resulting in rejection of the hybrid seed produced from that plot. During January 2010, female plants produced ISF in the primary spikes though the weather parameters during the flowering period (winter) were favourable to maintain pistillateness in the female parent. This could contaminate the secondary order spikes in seed production. The frequency of ISF plants was very high. When the cause for such a reversion was examined, it was found that there were some crop management problems due to which the crop received inadequate irrigation at wide intervals causing moisture stress. However, in the certified hybrid seed production plots of DCH 177 grown in three different farmers' fields under participatory seed production programme in Mahaboobnagar district, AP during the same period (winter season of 2009-10) the results were quite contrasting. In the first farmer's field, the crop was sown on 6-10-2009 in low-level fertility *Chalka* soil along with slope with recommended dose of fertilizers. The crop received less irrigations and due to the slope of the land, the plants could not receive adequate moisture for proper development. Because of moisture and nutrient stress, the female plants produced 5-8% of monoecious plants and 20-30% plants with ISF in primary, secondary and tertiary order spikes under optimum weather conditions. In the second farmer's field the crop was sown on 7-10-2009 in well-levelled moderately fertile soil with recommended dose of fertilizer and adequate irrigation at 10-12 days interval, DPC 9 produced only 2-4% monoecious plants and 5-8% female plants with interspersed staminate flowers that too from tertiary spikes onwards under similar favourable weather conditions. Though sowing was little late in the third farmers' field (crop was sown on 16-10-2009) in rice fallow with recommended dose of fertilizer and irrigation at 15 days interval, only 3-5% monoecious plants were observed while other female plants were free from ISF in primary and secondary order spikes. However, 2-5% female plants with ISF were observed from tertiary order onwards. Hence, sex expression in DPC 9 was normal pistillate under good nutrient management even though the temperature was more than 32°C favouring ISF production. Interestingly, we experienced two contrasting behaviour by DPC 9 sown during summer 2009 in two different locations. The crop was sown during February 2010 for foundation seed production at AAU, Anand in fertile soils with recommended dose of fertilizers and good crop management. The growth of plants was luxuriant and plants expressed complete pistillateness in all the spike orders up to the 7^{th} without any ISF even though the crop had experienced high temperatures of 45°C during summer. In this plot, the plants failed to produce seeds because of absence of male flower in the form of ISF. At the same time, breeder seed production was taken up at DSR, Hyderabad during January 2010 with recommended dose of fertilizers and seed crop management in black soil. The crop was well managed with irrigation at

20 days intervals during the crop growth period. In this case, the female plants produced 1-2% interspersed staminate flowers in primary and secondary orders, 3-5% in tertiary and quaternary orders and 6-8% in subsequent orders.

All the above observations are indicative that though the pistillate character is influenced by weather parameters, with high level of nutrition and required intervals of irrigation one could avoid stresses and maintain the pistillateness. Shifriss (1956) observed that sex tendency in castor is subject to extreme non-genetic fluctuations, female tendency is relatively strong in young plants and under moderate temperature, moderate vegetative growth conditions and high level of nutrition. In general, the harsher environment like moisture stress, high temperature, low nutrition/fertility, etc., may increases male flowers and ISF occur at the transition phase of these conditions. An understanding of the actual mechanism of sex expression influenced by the above mentioned factors is essential in seed production. By adopting proper agronomical practices especially moisture and nutrient stresses, seed with adequate genetic purity can be produced.

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Rapid laboratory tests useful for characterization and identification of castor, *Ricinus communis* L. genotypes

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Abstract

Variety identification has great significance from seed production, breeding as well as intellectual property rights point of view. Investigations were carried out under field and laboratory conditions to characterize 29 castor genotypes, including 10 hybrids and their parents on the basis of seed shape, colour, mottling, caruncle, seed weight and rapid chemical tests. The hybrids were more similar to their female parents with respect to seed morphology parameters. A key was prepared using the above parameters to identify the castor hybrids and their parents.

Keywords: Variety identification, seed morphology, GA_3, 2,4-D, seed keys

Introduction

Castor bean (*Ricinus communis* L.) is an indeterminate, non-edible oil seed crop grown in low rainfall regions of semi-arid tropics and sub-tropics. A number of hybrids of castor having a significantly higher yield potential than open pollinated varieties are being cultivated, both in rainfed and irrigated conditions. For an effective seed quality control programme it is very important to describe, differentiate and characterize these hybrids and their parental lines. Many of the descriptors that are conventionally used, based on plant morphology are unable to distinguish these genotypes. Also the expression of some of these characters is effected by the environment (Ramachandram and Ranga Rao, 1989). Hence there is a need to develop alternative descriptors which can supplement the morphological data. The development of laboratory tests to differentiate cultivars has been emphasized (Payne, 1979; Wagner and McDonald, 1981). Laboratory techniques offer the promise of being more rapid and less expensive than field testing. Further, analysis time is flexible and numerous additional traits useful in taxonomic characterizations are available. In the recent decades, considerable interest has been focused on the use of biochemical methods for plant variety discrimination and identification (Cheema *et al.*, 2010). The objective of the present study is to characterise 10 castor hybrids and their parental lines on the basis of seed morphology and rapid laboratory tests.

Based on the seed morphology and chemical tests, an identification key was developed for characterization of 10 castor hybrids and their parents. These markers have been used successfully for distinguishing both hybrids and their parents.

Materials and methods

Plant material: Genetically pure seed of 29 castor genotypes including six released varieties, 10 hybrids and their parental lines which are released since 1987 and the old ones still active in seed production chain, obtained from Directorate of Oilseeds Research, Hyderabad (Table 1) were studied for various morphological characters by visual observations and rapid chemical tests.

Seed morphology: The seeds were examined at maturity stage using a lens and characterized according to their shape (elongated, oval and square), colour (white, maroon, brown, dark chocolate and black), mottling (less conspicuous and conspicuous), caruncle (less conspicuous and conspicuous) and seed weight (low, medium and high).

Rapid chemical identification techniques:

a) Growth chamber tests (ISTA, 1996): The anthocyanin pigmentation on seedlings under controlled conditions was studied. Seedling were raised in 4" pots at 25°C under 24,000 Lux continuous light. Sterilized quartz sand was used as growth medium. They were watered every fourth day with distill water for rest of the days. Pigmentation was observed at 25 days after planting. The genotypes could be grouped into two categories *viz.*, green and purple.

b) Seedling growth response to 2,4-D: The response of genotypes to the herbicide, 2,4-D was tested at 5 mg/l and 10 mg/l concentrations at complete emergence of the seedlings and complete expansion of the cotyledonary leaves. Response was recorded as the time (in days) taken to show the signs of injury like tip drying, inward curling of leaf margins, stem thickening, stunted growth and finally death of the seedling.

c). Gibberellic acid (GA_3) test: Randomly selected 40 seeds were placed on a germination paper towel moistened with GA_3 @ 25 mg/l in four replications of 10 each and covered with another sheet of chemical moistened towel and rolled. The towel was kept vertically in a germinator at 25°C and 65-70% relative humidity for 7 days. The coleoptile length was measured on 7th day and the seedling growth response to GA_3 was studied and classified into three groups as a). High response (>39.6% increase over control), b). Medium response (26.7 to 39.6% increases over control) and c). Low response (< 26.7% increase over control).

Results and discussion

The data for seed and seedling characters presented in fig. 1 showed an ample variation among the varieties, hybrids and parental lines of castor for seed shape, colour, mottling, caruncle and 100 seed weight. Three types of seed shapes were observed in the genotypes studied. Among the 29 castor genotypes, majority of the genotypes (18) were found to be oval, five were elongate and only three were found to be square shaped. Different seed colours were noticed i.e., these main groups were then further subdivided into sub-groups on the basis of differences in seed colour. For example 19 genotypes with oval seeds are subdivided into four sub groups on the basis of seed colour (Fig. 1). Among them, DPC-9 with white and GCH-5 with maroon are distinct.

Genotypes with elongated seed shape were divided into four sub groups based on colour i.e., seeds with black, dark chocolate, brown and maroon. Latter three colours were also indentified with the oval category while black seed colour has been identified only with AKC 1 genotype while 50% of the genotypes with elongated seed shape were found to possess brown seeds. On the other hand, only one genotype (TMV5) has been identified with dark chocolate coloured seeds and one (JI 96) with maroon seeds. Only two distinct seed colours were identified in square shaped seeds. Of the three genotypes, two genotypes were distinguished with dark chocolate colour (DCS 5 and DCS 9) seeds, while only one genotype was distinct with maroon seed coat (DCH 177). Subsequent classification of oval seeds with brown seed coat were further made based on seed mottling i.e., less conspicuous (JI 35) and conspicuous (LRES 17, GAUCH 1, GCH 2, VI 9, VP 1, GCH 4, PCS 136 and TMVCH 1). The hybrids were more similar to their female parents with respect to the above parameters and these results are in accordance to Varier *et al.* (1999). A key based on the seed characters was constructed as an aid for the identification of these hybrids and their parental lines. The genotypes were also grouped on the basis of the reaction of seeds to the various chemical tests (*Table 2 to 4*) .

Growth chamber tests: The anthocyanin pigmentation on seedlings under controlled conditions was used to categorize the genotypes in two groups *viz.*, green and purple. Out of the 29 genotypes, nine had purple and the rest had green seedlings

2, 4-D test: Based on the degree of herbicide-injury or chemically altered growth to the herbicide 2, 4-D the genotypes were grouped as high, moderate and low sensitive. High sensitive varieties took less than nine days, moderately sensitive varieties took about 15 days, and low sensitive varieties showed no symptoms even after 20 days. Of the 29 genotypes, seven were categorized as high sensitive, 12 as moderately sensitive and ten genotypes as low sensitive (Table 3). Kumar *et al.* (1995) also distinguished pearl millet hybrids on the basis of 2,4-D test.

Gibberellic acid (GA_3) test: Study of seedling growth response to GA_3 indicated that the castor genotypes differed and thus growth response to GA_3 could be used as a criterion for distinguishing castor genotypes. Majority of the genotypes (18) exhibited medium response while seven genotypes (48-1,PCS 136, DPC 9, DCH 177, GCH 6, AKC 1 TMV 5) showed low and four genotypes (GCH 5, DCS 9, JP 65 and RHC 1) high seedling response to GA_3. Gupta and Agrawal, (1998) used coleoptiles growth response to GA_3 for distinguishing paddy varieties. These results are in line with results of Nethra *et al.* (2007) in rice. Response of seeds to different chemicals helped in grouping the genotypes rather than clear cut differentiation from each other. No individual chemical test was efficient in distinguishing the genotypes individually. However, they can be used as a supplement to each other.

The results of the present study suggests that the genotypes of castor examined can, not only be distinguished on the basis of seed characters; rapid laboratory tests such as presence of anthocyanin pigment, response of seedlings to GA_3 and 2,4-D could also be used for distinguishing castor genotypes.

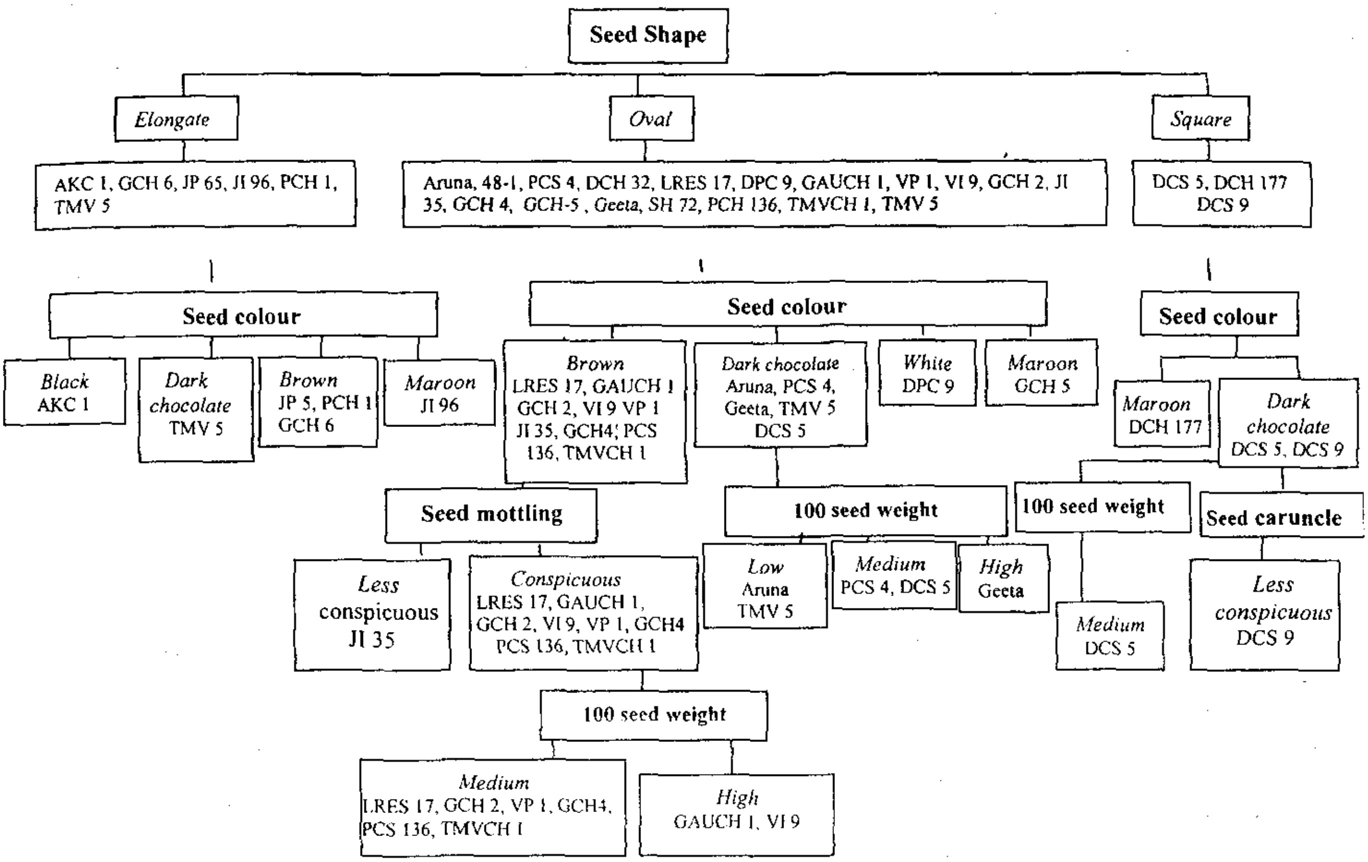

Fig. 1. Schematic diagram based on seed and seedling characters for identification of castor

Table 1. Varieties and hybrids along with parental lines of castor released after 1987

Variety	Hybrid	Female parent	Male parent
AKC 1	DCH 32	LRES 17	DCS 5
Aruna	DCH 177	DPC 9	DCS 9
GC 2	GAUCH 1	VP 1	VI 9
48-1	GCH 2	VP 1	JI 35
DCS 9	GCH 4	VP 1	48-1
Kranti	GCH 5	Geeta	SH 72
	GCH 6	JP 65	JI 96
	PCH 1	VP 1	PCS 136
	RHC 1	VP 1	TMV 5-1
	TMVCH 1	LRES 17	TMV 5

Table 2 Grouping of castor genotypes based on anthocyanin pigmentation

Purple	Green
Aruna , TMV 5, AKC 1, TMVCH 1, GCH 6, TMV 5-1,JP 65,48-1, GCH 4	GAUCH 1, VI 9, GCH 2 , JI 35, GCH 5, GEETA, PCH 1, SH 72, DCH 32, LRES 17, DCH 177, PCS 136, RHC 1, DCS 5, VP 1, JI 96, GC 4, DPC 9, GC 2, PCS 4

Table 3 Grouping of castor genotypes based on their sensitivity to the herbicide 2,4-D

Low	Moderately	High
Aruna, TMV 5, 48-1, Kranti, GAUCH 1, GCH 2,GCH 4, Geeta, TMVCH 1, TMV 5-1	AKC 1, DCS 9, GC 2, VP 1, JI 35, JP 65, VI 9, GCH 5, SH 72, LRES 17, PCH 1, RHC 1	PCS 136, DCH 32, DCS 5, DCH 177, DPC 9, GCH 6, JI 96

Table 4 Grouping of castor genotypes based on seedling growth response to GA_3

High	Medium	Low
GCH 5, DCS 9, JP 65, RHC 1	VP 1, VI 9, GAUCH 1, JI 35, GCH 2, GCH 4,PCH1 LRES 17, DCS 5,TMVCH 1, DCS 5,DCH 32,Geeta JI 96, Aruna, GC 2, PCS 4, TMV 5-1	48-1,PCS 136, DPC 9, DCH 177, GCH 6, AKC 1 TMV 5

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Genetic divergence in castor, *Ricinus communis* L.

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Abstract

Thirty-five castor genotypes were studied for nine characters *viz.*, days to 50% flowering, plant height (cm), number of nodes up to primary spike, number of spikes/plant, length of primary spike (cm), number of capsules/plant, 100 seed weight (g), oil content (%) and seed yield/plant (g) to determine the genetic divergence. These 35 genotypes were grouped into 6 clusters using D^2 analysis. Clustering pattern of genotypes did not follow geographical origin, suggesting that geographical isolation may not be the only factor causing genetic diversity. Among nine characters studied, number of capsules/plant followed by plant height and 100 seed weight contributed maximum towards genetic divergence. Based on these studies crosses may be made between the genotypes of cluster IV (Kranthi, 48-1, PCS 122, DCS 9, VP 1, LRES 17 and DPC 9) and cluster V (SKI 254), followed by cluster IV (Kranthi, 48-1, PCS 122, DCS 9, VP 1 LRES 17 and DPC 9) and cluster VI (RG 2777 and RG 2854) to obtain new desirable recombinants in castor.

Keywords: Genetic divergence, clusters, geographical isolation

Introduction

Castor (*Ricinus communis* L.) is one of the ancient non-edible oilseed crops of the world, which belongs to family Euphorbiaceae. The nature and magnitude of genetic divergence available in a species is essential for selection of desirable parents for hybridization. Mahalanobis' D^2 statistic is an effective tool in quantifying the degree of genetic divergence present in the material at genotypic level. It provides a quantitative measure of association between geographic distribution and genetic diversity based on generalized distance (Mahalanobis, 1936). Knowledge on the nature and the magnitude of genetic variability present in the crop species will play an important role in formulating a successful breeding programme

Materials and methods

The present investigation was carried out during the rainy season of 2005 at Agricultural College Farm, Bapatla, Guntur (Dt.), Andhra Pradesh, located at an altitude of 5.4m MSL, 15° 54' N latitude and 80° 90' E longitude. The soils are black cotton type with clayey texture The experimental material comprising 35 genotypes were obtained from Directorate of Oilseeds Research (DOR), Hyderabad. The experiment was conducted in a randomized block design with two replications. Each genotype was sown in three rows of 6m length with a row to row spacing of 90cm and plants spaced at 60cm within a row. The crop was grown as per the recommended crop production practices. The mean data collected on nine characters was analyzed using Mahalanobis's D^2 analysis to determine the genetic divergence among the genotypes.

Results and discussion

For a successful breeding programme, the diversity of parents is of utmost importance, since the crosses made between the parents with maximum genetic divergence would more likely yield desirable recombinants in the progenies. However it is desirable to select suitable genetically divergent parents, based on information about the genetic variability and genetic diversity present in the available germplasm. The multivariate analysis using Mahalanobis' D^2 statistic is a useful statistical tool for measuring the genetic diversity in germplasm collections with respect to the characters considered together. Further selection of diverse parents for hybridization programme will be effective by the identification of characters responsible for the total genetic diversity among the populations (Singh and Chaudhary, 1977).

The genetic diversity study using statistic analysis indicated that the distribution of 35 genotypes into six clusters was at random with maximum number of 17 genotypes in cluster I followed by cluster II and IV with seven genotypes each (Table 1). The distribution of genotypes in six clusters indicated that the geographical diversity and genetic diversity were not related. This suggests that there are forces other than geographical separation such as natural and artificial selection, exchange of breeding material, genetic drift and environmental variation. The results were in accordance with the findings of Bhatt and Reddy (1987).

The results revealed that number of capsules/plant contributed maximum towards genetic divergence followed by plant height, 100 seed weight, oil content, yield/plant, number of spikes/plant, length of primary spike, number of nodes up to primary spike and days to 50% flowering (Table 2). Among the clusters, cluster IV containing high yielding, released varieties like Kranti, DCS-9, 48-1 recorded highest number of capsules and seed yield/plant. These observations are in accordance with the findings of Bhatt and Reddy (1987) and Sevagaperumal et al. (2000) (Table 3).

The intra and inter cluster D^2 values revealed that inter cluster D^2 values were greater than intra cluster D^2 values. The maximum inter cluster D^2 value was observed between cluster IV and V followed by cluster IV and VI and the least inter cluster D^2 values were observed between cluster I and V followed by II and III. Based on these studies crosses may be made between the genotypes of cluster IV *viz.*, Kranthi, 48-1, PCS 122, DCS 9, VP 1, LRES 17, DPC 9 and cluster V *viz.*, SKI 254, followed by cluster IV *viz.*, Kranthi, PCS 122, DCS 9, VP 1, LRES 17, DPC 9 and Cluster VI *viz.*, RG 2777, RG 2854 to obtain new desirable recombinants in castor. Maximum intra cluster D^2 value was observed in cluster IV followed by cluster II, cluster I and cluster VI. The intra cluster D^2 values in cluster III and V were zero as they consists of one genotype in each cluster.

Table 1 Distribution of 35 genotypes of castor in different clusters

Cluster number	Genotypes	Number of genotypes
I	SKI 283, RG 1740, DCS 84, PCS 121, AKC 1, SKI 252, PCS 504, PCS 138, JI 220, DCS 33, DCS 85, RG 90, SKI 291, PCS 128, SKI 232, JI 321, RG 2850.	17
II	JI 244, SKI 299, SKI 281, JI 273, PCS 137, PCS 124, JI 240.	7
III	RG 279	1
IV	Kranthi, 48- 1, PCS 122, DCS 9, VP 1, LRES 17, DPC 9	7
V	SKI 254	1
VI	RG 2777, RG 2854	2

The highest intra cluster distance in cluster IV indicates the presence of wide genetic diversity among the genotypes *viz.*, Kranthi, 48-1, PCS 122, DCS 9, VP 1, LRES 17, DPC 9. Cluster mean values showed a wide range among the characters studied, which indicates the presence of variation among the genotypes studied. For a successful breeding program selection of genetically diverse parents is an important prerequisite so as to obtain better and desirable recombinants. Similar results were reported by Singh and Srivastava (1978), Bhatt and Reddy (1987), Sevagaperumal *et al.* (2000) in castor.

Table 2 Cluster means of different characters and % contribution towards genetic divergence

Character	I	II	III	IV	V	VI	% contribution towards genetic divergence
Days to 50% flowering	57.2	49.0	70.0	54.6	59.5	81.0	0.1
Plant height (cm)	59.2	77.0	98.4	52.5	49.0	98.7	26.3
No. of nodes up to primary spike	15.7	18.6	22.9	15.7	14.6	23.1	0.6
No. of spikes per plant	6.2	7.0	4.0	11.4	7.1	4.6	4.5
Length of primary spike (cm)	27.3	30.2	42.5	41.7	21.6	45.9	3.8
Capsules/plant	192.2	140.6	241.3	324.1	97.3	191.3	34.4
100 seed weight (g)	23.3	28.2	19.5	23.4	28.4	39.1	20.3
Oil content (%)	49.9	51.5	50.6	50.2	54.6	52.7	4.8
Yield/plant (g)	120.8	110.8	133.3	221.6	62.6	206.2	4.7

Table 3 Intra and cluster average divergence (D^2) values of clusters estimated for 35 genotypes of castor

Cluster	I	II	III	IV	V	VI
I	207.65 14.41	570.25 23.88	519.84 22.80	777.85 27.89	447.75 21.16	902.40 30.04
II		215.80 14.69	466.13 21.59	1436.41 37.90	746.93 27.33	589.52 24.28
III			0.00 0.00	695.90 26.38	1276.63 35.73	472.19 21.73
IV				382.98 19.57	1653.24 40.66	1338.83 36.59
V					0.00 0.00	1290.97 35.93
VI						197.12 14.04

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Studies on genotypic correlations and path coefficient analysis of seed yield and yield components in castor genotypes

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Abstract

The investigation was undertaken with an objective to study genotypic correlations and path coefficient analysis in 62 castor genotypes including two cheeks, Kiran and 48-1 during the rainy season of 2007. Character associations revealed strong positive association of seed yield with total and effective length of primary (main)

spike, number of capsules on main spike, number of effective spikes/plant and oil content. However, path coefficient analysis revealed maximum direct effect of number of capsules on main spike, number of effective spikes/plant and oil content on seed yield. Moreover, the indirect effects through total and effective length of primary spike were appreciable.

Keywords: Path coefficient analysis, correlations

Introduction

Yield is a complex character and it is influenced by several genetic factors interacting with environment. A clear understanding of the association of plant characters with seed yield is necessary for successful crop improvement programme. Correlation coefficients reveal the magnitude and the direction of association of yield components among themselves and with seed yield while path coefficient analysis helps in partitioning of the correlation coefficient into the direct and indirect effects of yield components on seed yield. In addition, path analysis gives a clear idea of nature of association among the yield components and their relative contribution to yield.

Materials and methods

The experimental material for investigation comprised of 64 castor genotypes including 13 advanced lines, 39 germplasm accessions, two pistillate lines, two released varieties and two cheeks available at Directorate of Oilseeds Research, Hyderabad. The experiment was conducted in a randomized block design and replicated twice during the rainy season of 2007 at DOR, Hyderabad. Each genotype was grown in a two row plot of 4.5 m length, with a spacing of 95 cm x 45 cm.

Results and discussion

In general, values for genotypic correlations were higher than the phenotypic correlations (Table 1), indicating that strong inherent associations were some what masked at phenotypic level due to environmental effects, as reported by Giriraj *et al.* (1973) and Bhatt and Reddy (1981). The trait number of capsules on main spike recorded highest positive and significant association with seed yield which has also been reported by Aswani Kumar *et al.* (2003) and Ramu *et al.* (2005). Other traits like effective and total length of primary, oil content and number of effective spikes/plant were also significantly associated with final seed yield. Similar results were reported by several authors (Yadava *et al.*, 2004; Ramu *et al.*, 2005; Lavanya *et al.*, 2006). Other characters *viz.* number of nodes and plant height up to the primary spike and 100 seed weight expressed a non significant correlation with seed yield.

The correlation studies were further strengthened by path coefficient analysis establishing the interdependence of characters and the extent of influence of independent characters either directly or indirectly on seed yield. Studies conducted by different castor researchers established that the characters, number of capsules/primary and secondary, number of capsules/plant, 100 seed weight, nodes to primary raceme, number of spikes/plant, total and effective spike length and oil content had direct and positive effect on seed yield/plant (Lavanya *et al.*, 2006).

Among all the traits, number of capsules on main spike had highest direct positive effect on seed yield followed by number of effective spikes/plant. The results are in conformity with Patel and Jaimini (1991) and Ramu *et al.* (2005). The present study also showed that oil content had a positive direct effect on seed yield, as reported by Ramu *et al.* (2005). The present study indicated that the characters, effective spike length, plant height and number of nodes up to the primary spike had a positive direct effect while 100 seed weight and total spike length had a negative direct effect on seed yield. Similar positive direct effect on seed yield was also reported by Ramesh *et al.* (2001). However, Yadava *et al.* (2004) reported negative direct effect of 100 seed weight on seed yield.

Table 1 Estimates of correlation coefficient between seed yield and yield components in 62 genotypes of castor

Characters	No. of nodes up to primary raceme	Plant height up to primary raceme (cm)	Total spike length (cm)	Effective spike length (cm)	No. of capsules on main spike	No. of effective spikes/plant	100 seed weight (g)	Oil content (%)	Final seed yield/plant (g)
No. of nodes up to primary raceme	1.000	0.7656**	0.5558**	0.2633**	0.1562	-0.1804	0.2668**	0.0190	0.1194
Plant height up to primary raceme (cm)		1.000	0.3224**	0.0079	-0.0251	-0.1430	0.1943*	-0.0879	0.0287
Total spike length (cm)			1.000	0.6941**	0.5366**	-0.0203	0.1272	0.2824**	0.2846**
Effective spike length (cm)				1.000	0.6232**	-0.0050	0.0083	0.4296**	0.3457**
No. of capsules on main spike					1.000	0.1248	-0.0891	0.3417**	0.4606**
No. of effective spikes/plant						1.000	-0.3067**	0.0659	0.2025*
100 seed weight (g)							1.000	0.0219	0.1373
Oil content (%)								1.000	0.3037**

** significant at 1 % level; * significant at 5% level

The indirect effects of the number of capsules/main spike via plant height up to the primary spike and 100 seed weight were negative and via total and effective length of primary spike, number of effective spikes/plant and 100 seed weight was positive. However, the indirect effect of number of effective spikes/plant *via* number of nodes and plant height up to the primary spike, total and effective length of primary spike and 100 seed weight were negative and *via* number of capsules on the primary spike and oil content were positive towards seed yield/plant.

Positive and significant correlation of number of capsules on the primary spike and oil content with total and effective length of primary spike and the direct effect of these two traits with seed yield observed in the present study indicated that the three characters *viz.*, total and effective length of primary spike, number of capsules on the primary spike and oil content contribute to the oil yield and can be used as selection criteria in the segregating generations.

Table 2 Estimation of phenotypic path coefficients between yield and its contributing characters in 62 castor genotypes

Characters	No. of nodes up to primary raceme	Plant height up to primary raceme (cm)	Total spike length (cm)	Effective spike length (cm)	No. of capsules on main spike	No of effective spikes/plant	100 seed weight (g)	Oil content (%)	Correlation with seed yield
No of nodes up to primary raceme	**0.012**	0.009	0.001	0.003	0.002	-0.002	0.003	0.000	0.119
Plant height up to primary raceme (cm)	0.039	**0.051**	0.015	0.000	-0.001	-0.007	0.010	-0.004	0.028
Total spike length(cm)	-0.042	-0.024	**-0.075**	-0.052	-0.040	0.001	-0.009	-0.021	0.284**
Effective spike length (cm)	0.024	0.000	0.063	**0.092**	0.057	-0.005	0.000	0.039	0.345**
No of capsules on main spike	0.060	-0.009	0.206	0.242	**0.338**	0.048	-0.034	0.132	0.460**
No of effective spikes/plant	-0.040	-0.032	-0.006	-0.001	0.028	**0.225**	-0.069	0.014	0.202*
100 seed weight (g)	0.062	0.045	0.027	0.001	-0.020	-0.071	**-0.233**	0.005	0.137
Oil content (%)	0.002	-0.012	0.036	0.058	0.046	0.009	0.003	**0.136**	0.303**

**significant at 1 % level; Bold : Direct effect; *significant at 5% level; Normal : Indirect effect; Residual effect : 0.8296

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Quality hybrid seed production in castor by manipulation of pistillate character

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Abstract

The effect of nitrogen (N) and a growth regulator, ethrel on sex expression, yield and its contributing characters and seed quality were studied on M-574 which is the female parent of a promising castor hybrid, DCH-519. The study included five varying levels of N from 40, 60, 80, 100 and 120 kg/ha, two doses of ethrel -200 and 400 mg/l along with 40 kgN/ha. The analysis of variance revealed significant differences among the treatments for the expression of pistillateness and number of interspersed staminate flowers (ISFs) in primary and secondary order

spikes. Among different nitrogen treatments, the seed parent M-574, which received 100 kg N/ha recorded less number of ISF and a plant stand with higher frequency of pistillate flowers. However, the two treatments, ethrel @200 mg/l and 400 mg/l along with 40 kg N/ha suppressed the ISFs, enhanced the number of pistillate flowers in seed parent M-574 and resulted in higher genetic purity.

Keywords: Interspersed staminate flowers, ethrel, pistillate expression

Introduction

Castor is sexually polymorphic species with different sex forms *viz.*, monoecious, pistillate, sex revertants and pistillate with interspersed staminate flowers (ISF) in between pistillate flowers. Sex expression in castor is highly influenced by environmental factors like high day temperature (>32°C), photo period, fertility, age of the plant, nutrition, etc. (Shifriss, 1960; Ramachandram and Ranga Rao, 1988; DOR, 2009).

Hybrid seed production in castor is revolutionized by the identification of pistillate lines. The instability of pistillate lines due to the occurrence of ISFs is causing a serious problem in maintaining genetic purity of the seed. Application of nitrogen (N) plays a key role in improving the pistillate character (Shifriss, 1960; Zimmerman and Smith, 1966; Narkhede *et al.*, 1984; DOR, 1999). The manipulation of sex towards induction of pistillate flowers or reduction of ISF will be helpful in overcoming the problems associated with maintenance of pistillate lines and hybrid seed production irrespective of the season during the seed production programme.

Materials and methods

The present investigation was carried out at the Seed Research and Technology Centre (SRTC), Acharya N.G.Ranga Agricultural University, Rajendranagar, Hyderabad in seed production plots of DCH 519 involving M-574 (female) and DCS-78 (male). The experiment was laid out with seven treatments in a randomised block design with three replications during the winter season of 2008. The different nitrogen treatments imposed were 40, 60, 80, 100, 120 kg/ha, 40 kg N + 200 mg/l ethrel/ha and 40 kg N + 400 mg/l ethrel/ha. Nitrogen was applied in three splits at the time of sowing, primary order and secondary order spike initiation stages. Recommended doses of phosphorous (60 kg/ha) and potassium (60 kg/ha) were applied in all the seven treatments. The data were collected on number of pistillate plants/plot, number of ISF in different order spikes, total plant stand/plot, days to initiation of first raceme, days to 50% flowering of first raceme, days to maturity of first raceme, plant height up to primary spike (cm), number of nodes up to primary spike, effective length of primary spike (cm), 100 seed weight (g), seed yield/plant (g) and oil content (%). Standard statistical tools were used to estimate the ANOVA for different characters.

Results and discussion

Analysis of variance revealed the existence of significant differences among the treatments with respect to the expression of pistillateness and ISF in primary and secondary order spikes. Among different N treatments, the seed parent, M-574, which received 100 kg/ha recorded less number of ISF and maximum number of plants with higher frequency of pistillate flowers (Table 1).

Similar results on the effect of N in increasing the pistillateness of the female lines was reported from Tindivanam, Palem and Hyderabad (DOR, 1999). The number of plants with ISF decreased while proportion of pistillate plants increased with higher levels of N at DOR, Hyderabad and in Tindivanam. Application of 40 kg N as basal followed by 20 kg N each at 35, 70 and 105 days recorded the highest mean seed yield of 1745 kg/ha in three isolations for two years at Tindivanam.

However, there was no effect of N up to 125 kg/ha and irrigation up to 1.25 IW/CPE on the percentage of ISF, pistillate plants and reversion below fourth order of spikes at S.K. Nagar. Genotypic differences in the response of pistillate lines Geeta and VP-1 to N application were reported at S.K. Nagar and Junagadh where the pistillate line Geeta gave higher seed yield compared to VP-1 with higher doses of N (100-125 kg/ha) and irrigation level (IW/CPE) above one. However, the influence of N (0, 40, 80, 120 kg/ha) on number of ISF was not significant in 11 interspersed (ISF) and five non-interspersed (NISF) breeding lines isolated from late revertant pistillate progenies of VP-1 at DOR, Hyderabad (Lavanya, 2002).

The role of ethrel on sex expression as reported by Gopalakrishna Murthy *et al.* (2003) in castor and Balasubramanian and Narayana Swamy (1980) in *Acalypha indica* was confirmed in the present study. Spraying of ethrel @ 200 and 400 mg/l along with 40 kg N/ha suppressed the ISF and enhanced the number of pistillate flowers in M-574 and resulted in improving genetic purity and seed quality (Table 1). The effect of N and ethrel treatments was found to be significant for yield and its contributing characters.

Among the various doses of N applied, the plants which received 100 kg/ha were early in flowering and maturity. Increase in N dose also increased 100 seed weight and seed yield except in the case of the highest dose of 120 kg/ha. Ethrel treatments exhibited suppressive effect on vegetative growth when compared to N treatments. Both the treatments of ethrel improved the spike length, seed yield, oil content and 100 seed weight. The seed quality was also high with ethrel treatments. Hence, it was concluded that 40 kg N/ha along with 200 mg/l/ha was very effective in obtaining high quality seed by suppression of ISF in seed parent M-574 of castor hybrid, DCH-519.

Table 1 Effect of different treatments on seed yield and yield components in seed parent M-574

Nitrogen (kg/ha)	No. of ISF on primary spike	No. of ISF on secondary spike	Days to initial flowering of primary spike	Days to 50 % flowering of primary spike	Days to maturity	Plant height (cm)	No. of nodes up to primary spike	Length of primary spike (cm)	100 seed weight (g)	Seed yield (g/plant)	Oil content (%)
60	20	17	45	48	131	50	13.0	52	25.0	58.8	51.5
80	18	16	43	47	129	51	14.0	54	25.0	59.4	51.6
100	8	7	41	44	125	58	15.0	60	28.0	64.5	51.6
120	10	9	43	47	127	58	14.6	55	25.5	63.3	51.8
40+Ethrel 200 mg/l	5	5	42	44	126	48	14.6	56	28.7	64.8	51.6
40+Ethrel 400 mg/l	4	6	41	44	126	46	14.6	60	26.7	65.3	52.2
40	23	21	45	49	131	49	14.0	51	25.0	58.2	51.5
Mean	13	11	43	46	128	51	14.0	56	26.2	62.0	51.7
SEm ±	2	1	1	1	1	1	0.4	1	0.8	1.6	0.4
CD (P=0.05)	5	3	2	2	3	2	1.3	4	2.5	4.9	1.1
CV (%)	0	0	2	3	1	2	5.0	4	5.3	0.0	1.2

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Heterosis and inbreeding depression analysis in castor, *Ricinus communis* L.

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Abstract

An attempt was made to study the extent of inbreeding depression in both selfed and open pollinated populations for ten characters in eight selected crosses in the second filial genera-tion. The magnitude of inbreeding depression was high under strict selfing than open pollination of F_1 plants. Majority of the crosses exhibited negative values for both heterosis and inbreeding depression for earliness and related traits indicating the predominance of additive gene effects. However for seed yield and primary spike characters both the heterosis and inbreeding depression values were positive inferring the predominance of non-additive gene action. Based on the results, it is concluded that recommendation of F_2 seed for commercial crop production is not economical. In crosses involving DPC-9 (female parent) as height and maturity parameters were relatively on par with majority of good male combiners, the F_2 seed could be suggested for sowing, if the cross is highly heterotic with no inbreeding depression. The crosses possessing non-significant inbreeding depression with significant desirable heterosis could be utilized to isolate transgressive segregants in F_2 and subsequent generations.

Keywords: Castor, heterosis, inbreeding depression

Introduction

With the increased production costs of commercial crops like cotton, chillies, castor crop has gained importance as an alternate commercial crop due to its yield potential and low input costs especially in Andhra Pradesh, Maharashtra, Karnataka and Madhya Pradesh under rainfed conditions. In spite of the availability of many high yielding hybrids, farmers would prefer using F_2 seed for commercial cultivation since the cost of the hybrid seed is high. Inbreeding depression, in general, is less in castor, but reports to state the extent of inbreeding depression are lacking. Moshkin (1986) reported that to use inter-line hybrids of castor, it is necessary to clarify, whether the increased yield of seeds is retained during subsequent generation and whether it is possible to use them for sowing in the second generation. Hence, it is worthwhile to have complete information on the extent of heterosis in related cross combinations and also to study the extent of inbreeding depression for the possible use of F_2 seed on commercial scale.

Materials and methods

Among the 36 crosses obtained from nine lines and four testers, eight crosses were selected based on seed yield of F_1 hybrids, two each from four different pisitillate entries. These eight crosses were selfed to produce the F_2 generation during the rainy season of 2001. Open pollinated seeds were also collected from F_1 plants for comparative study of extent of inbreeding depression under selfed and open pollinated conditions. The F_1 and F_2 generations (both selfed and open pollinated) along with their parents were evaluated during the winter season of 2001 laid out in a randomized block design and replicated twice. The plot size for each entry was two rows of 5 m length for parents and F_1s and five rows of 5 m length for F_2 generation with spacing of 90 cm x 60 cm. A random sample of five plants/plot from parents and F_1 and 30 plants/plot from F_2 generation in each replication were utilized to record the observations on ten characters *viz.*, days to 50% flowering, days to maturity, number of nodes, plant height, primary spike length, effective spike length, number of capsules/primary spike, 100 seed weight, seed yield/plant and oil content. Mid parental heterosis and inbreeding depression for each character was calculated (Miller and Marani, 1963).

Results and discussion

Heterosis and inbreeding depression values are presented in table 1. Majority of the crosses exhibited significant negative inbreeding depression, indicating the higher values in F_2 than the F_1 generation. However, positive inbreeding depression is desirable for earliness and related traits to obtain desirable segregants in F_2 and subsequent generations. Heterosis values were negative and significant in majority of the crosses for these traits. Further, the crosses exhibiting higher negative heterosis also exhibited higher values of negative inbreeding depression, suggesting the predominance of additive gene effects.

For the traits *viz.*, primary spike length, effective spike length, number of capsules/primary spike, in general, the magnitude of inbreeding depression was high in selfed compared to open pollinated population, indicating that the inbreeding depression would be high under strict inbreeding than in open pollinated F_1 individuals. Further, the crosses showing higher heterotic effects consequently expressed the higher values of inbreeding depression in most of the cases, inferring the predominant role of non-additive gene action. However, the cross, Geeta x 48-1 exhibited non-significant inbreeding depression and significant negative heterosis for primary spike length, effective spike length and number of capsules/primary spike. The crosses, VP-1 x DCS-5 and VP-1 x DCS-27 for primary spike length, DPC-9 x DCS-9 for effective spike length and VP-1 x DCS-5, DPC-9 x DCS-9 and LRES-17 x DCS-27 for number of capsules/primary spike exhibited desirable non-significant inbreeding depression, though they had significant positive heterosis. It suggests the possibility of fixing of additive gene effects for the traits in these crosses. These results are akin to the reports of Hirve and Tiwari (1991) who reported that inbreeding depression was absent in Indian mustard.

In case of 100 seed weight, the magnitude of inbreeding depression was high in selfed F_2 than open pollinated F_2 population barring the crosses which involve DCS-27 as male parent. Since the 100 seed weight of DCS-27 parent was least, open pollination of the hybrids of DCS-27 had negative inbreeding depression. The crosses exhibiting significant positive inbreeding depression *viz.*, DPC-9 x DCS-27, VP-1 x DCS-5, Geeta x SH-72 also recorded significant positive heterotic effects indicating the presence of dominance and over dominance for 100 seed weight, wherein heterosis breeding could be rewarding for improvement of the trait. Similarly, Pathak *et al.* (1988) reported high inbreeding depression for 100 seed weight in castor. However, the crosses, DPC-9 x DCS-9, VP-1 x DCS-27, LRES-17 x SH-72 and Geeta x 48-1 recorded non-significant inbreeding depression in selfed F_2 population though they had significant positive heterosis indicating the predominance of fixable gene effects.

Similarly, for seed yield/plant the magnitude of inbreeding depression was high under selfed F_2 compared to open pollinated F_2 population. The inbreeding depression was high under strict selfing than the open pollination of F_1 hybrids. Among eight crosses, studied seven crosses had significant positive values for both inbreeding depression and heterosis, indicating the predominance of non-additive gene components in governing seed yield. Similar results were reported by Pathak *et al.* (1988) in castor and Singh and Rai (1995) in Indian mustard. Therefore, the desirable best crosses can be utilised in the breeding programme and rapid progress can be achieved by family selection following intermating in subsequent generations for the improvement of seed yield. However, the cross, Geeta x 48-1 exhibited non-significant inbreeding depression in selfed F_2 condition besides expressing positive heterosis. It indicates the predominance of additive type of gene action. These results are akin to the reports of Yazdi-Samadi *et al.* (1975) who reported negligible inbreeding depression in safflower. Hence, the cross could be used to produce biparental progenies and **evaluate subsequently to get** superior segregates which might be handled through pedigree method of breeding.

Table 1 Heterosis and inbreeding depression in eight selected crosses for ten characters in castor

Cross	Days to 50% flowering			Days to maturity			Number of nodes			Plant height			Primary spike length		
	Heterosis	Inbreeding depression: F_1 selfed	Inbreeding depression: F_1 open pollinated	Heterosis	Inbreeding depression: F_1 selfed	Inbreeding depression: F_1 open pollinated	Heterosis	Inbreeding depression: F_1 selfed	Inbreeding depression: F_1 open pollinated	Heterosis	Inbreeding depression: F_1 selfed	Inbreeding depression: F_1 open pollinated	Heterosis	Inbreeding depression: F_1 selfed	Inbreeding depression: F_1 open pollinated
VP-1 x DCS-5	-20.92 **	-3.62	-0.72	-9.27 **	-6.29 *	-5.66 **	-17.09 **	-27.39 **	-15.39 **	27.06 **	0.15	2.95	15.61 *	14.12	7.51
VP-1 x DCS-27	-25.64 **	-48.28 **	-30.35 **	-8.29 **	-14.76 **	-9.34 **	-11.82 **	-34.08 **	-15.08 **	50.87 **	2.26	9.43	38.42 **	11.12	12.17
DPC-9 x DCS-9	-16.25 **	-5.97	-14.18 **	-5.62 **	-3.76	-8.15 **	-6.13	-13.73 **	-3.92	-17.40 **	-3.51	-9.13	9.19	3.81	-0.15
DPC-9 x DCS-27	-17.99 **	-18.71 **	-13.55 **	-4.90 **	-1.18	1.18	2.44	-5.02	-3.44	0.62	34.34 **	24.14 **	20.93 **	50.47 **	21.77 **
LRES-17xDCS-27	-19.66 **	-9.79 *	-13.29 **	-11.69 **	-13.74 **	-11.50 **	-1.72	-13.45 **	-7.02 *	20.37 *	-21.71 *	-10.68	4.25	8.99	8.38
LRES-17 x SH-72	-24.14 **	-11.89 **	-2.10	-5.67 **	-11.53 **	-8.41 **	-18.52 **	-24.72 **	-26.99 **	-10.86 *	-33.08 **	-19.85 **	-2.23	16.77 *	9.37
Geeta x SH-72	-3.94	-8.72 **	-3.08	-5.67 **	-3.91	-0.56	-8.76 **	-3.58	2.23	-18.49 **	-19.93 **	-6.45	14.22 **	20.56 **	3.15
Geeta x 48-1	-8.99 **	-1.20	-3.59	-6.78 **	-4.07	-4.36 *	-8.62 **	-5.47	-7.96 **	-20.61 **	-3.44	-1.72	-26.65 **	-3.83	1.31

Cross	Effective spike length			Number of capsules per primary spike			100 seed weight			Seed yield/plant			Oil content		
	Heterosis	Inbreeding depression: F1 selfed	Inbreeding depression: F1 open pollinated	Heterosis	Inbreeding depression: F1 selfed	Inbreeding depression: F1 open pollinated	Heterosis	Inbreeding depression: F1 selfed	Inbreeding depression: F1 open pollinated	Heterosis	Inbreeding depression: F1 selfed	Inbreeding depression: F1 open pollinated	Heterosis	Inbreeding depression: F1 selfed	Inbreeding depression: F1 open pollinated
VP-1 x DCS-5	26.64 **	20.11 **	15.71 *	42.43 **	4.64	4.82	24.41 **	8.95 **	5.08	74.90 **	22.33 **	18.43 **	3.80 **	-1.31	5.90 **
VP-1 x DCS-27	45.26 **	18.23 **	13.15 *	55.08 **	28.96 **	23.41 **	9.39 **	4.42	-5.21	94.79 **	29.27 **	22.31 **	-8.24 **	-1.12	-6.86 **
DPC-9 x DCS-9	13.21 *	2.30	5.32	19.70 **	4.57	0.69	25.77 **	1.75	0.69	29.66 **	26.74 **	14.54 **	-5.09 **	-0.77	-1.97
DPC-9 x DCS-27	30.03 **	52.54 **	21.75 **	45.71 **	50.91 **	18.25 **	17.10 **	16.99 **	8.62 *	63.04 **	43.14 **	21.32 **	-1.65	6.25 **	0.50
LRES-17 x DCS-27	5.66	7.33	6.67	21.20 **	13.40	9.99	-3.06	3.39	-5.70	78.31 **	44.18 **	31.98 **	-3.66 **	3.31 **	-2.67 *
LRES-17 x SH-72	0.07	24.18 **	11.61	0.63	30.64 **	12.08	5.19 *	3.75	1.07	63.73 **	26.48 **	17.07 **	2.06 *	4.58 **	6.19 **
Geeta x SH-72	13.07 **	20.36 **	0.47	-0.16	5.38	4.24	9.65 **	12.87 **	3.21	28.64 **	27.61 **	17.33 **	2.52 **	4.22 **	4.53 **
Geeta x 48-1	-23.99 **	2.25	10.30	-24.08 **	-13.09	-4.76	14.56 **	-3.98	0.54	21.01 **	4.28	14.70 **	-0.23	-0.74	3.91 **

*, ** Significant at 5% and 1% level, respectively

For oil content, two crosses *viz.*, LRES-17 x SH-72 and Geeta x SH-72 exhibited significant positive inbreeding depression and also had significant positive heterosis suggesting the preponderance of non-fixable gene effects. The cross LRES-17 x DCS-27 recorded significant positive inbreeding depression in selfed F_2 population and significant negative heterosis in F_1 suggesting the presence of epistatic interactions in governing the trait. However, the cross, VP-1 x DCS-5 exhibited non-significant negative inbreeding depression, though it had significant positive heterosis inferring the predominance of fixable gene effects. Hence, it could be possible to isolate desirable transgressive segregants from this cross in F_2 and subsequent generation, which might be handled through pedigree method of breeding for improving oil content.

For the utilisation of F_2 seed for commercial crop production, it is essential to have low inbreeding depression for seed yield and also they should be uniform in height and maturity duration. However, the F_2 population of the crosses involving LRES-17 as female parent showed large variation in plant height and days to maturity, while the crosses with VP-1 exhibited large variation in plant height. Further, most of the crosses studied exhibited high magnitude of inbreeding depression for seed yield/plant barring the cross, Geeta x 48-1. It was also found that the decrease in seed yield was several times higher when compared to the hybrid seed cost. Based on the results F_2 seed for commercial crop production is not a viable preposition. However, the crosses involving DPC-9 as female parent whose height and maturity parameters were relatively on par with majority of good male combiners, the F_2 seed could be suggested for sowing, if the cross is highly heterotic with no inbreeding depression.

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Generation mean analysis for yield contributing characters in castor, *Ricinus communis* L.

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Abstract

Estimates of gene effects through joint scaling test of three and two parameter and sequential fit models in four crosses involving eight castor genotypes for ten characters were investigated. It was noticed that simple additive dominance model showed good fit for two crosses *viz.*, DPC-9 × RG-2374 and LRES-17 × RG-1471 for number of nodes upto primary spike and 100 seed weight, respectively. In remaining crosses digenic/non-allelic interactions were involved in controlling the expression of the traits. As seed yield is the main concern, five parameter sequential fit model involving different types of interactions *viz.*, m, [d], [h], [i] and [l], m, [h], [i], [j] and [l], m, [d], [h], [i] and [j] was observed in the crosses two, three and four, respectively. Sequential fit three parameter (m, [h] and [i]) model was the best fit for cross 1. Duplicate type of epistasis was observed for various characters in all the crosses. Simple additive dominance model exhibited lack of good fit for most of the characters in all the four crosses studied. Dominance and epistatic interactions were playing a major role in the inheritance of yield and its components in castor. It can be categorically stated that, reciprocal recurrent selection or diallel selective mating are the need of the hour to modify the genetic architecture of castor for attaining higher yields.

Keywords: Generation mean, gene effects, yield components, castor

Introduction

Seed yield is the ultimate product of action and interaction of a number of yield components, which are governed by a large number of genes having small effects and are greatly influenced by environment. Information on the presence of type of epistatic gene effects in the inheritance of various quantitative traits is important for adopting suitable breeding procedures to improve the traits. Generation mean analysis (Hayman, 1958) gives a comprehensive picture of gene action controlling the trait. It is relatively a simple first degree statistically analyzed technique to know the predominant gene effects that are responsible in effecting the variation of a character. Thus, in the present investigation, genetic parameters *viz.*, additive, dominance and epistatic gene effects were estimated through genertion mean analysis for ten quantitative traits in four crosses of castor.

Materials and methods

Eight parents were selected for making four independent crosses namely, Kranthi × RG-224 (C1), DPC 9 × RG-2374 (C2), VP-1 × RG-1719 (C3) and LRES-17 × RG-1471 (C4) to study the gene effects through generation mean analysis. The experiment with six generations (P_1, P_2, F_1, F_2, B_1 and B_2s) generated in previous two seasons was grown in a randomized block design with three replications at College Farm, College of Agriculture, Rajendranagar, Hyderabad. Recommended package of practices were adopted to grow a healthy crop. A spacing of 90 cm x 60 cm was maintained in all the experiments. Need based irrigations were given. Necessary prophylactic measures were adopted to save the crop from pests and diseases. The parents and F_1s were sown in two rowed plots, F_2s in eight rowed plots and B_1s and B_2s were grown in four rows each of 5 m length. The observations were recorded on individual plant basis in each replication on five randomly selected plants in each parent and F_1, ten plants in each B_1 and B_2, and twenty plants in F_2 population for ten quantitative traits in each cross. Joint scaling tests of Cavalli (1952) and sequential fit model of Mather and Jinks (1982) were adopted to trace out precise estimates and magnitude and direction of genetic parameters. This technique was employed under three parameter (*viz.*, m, [d] and [h]) and six parameters (*viz.*, m, [d], [h], [i], [j] and [l]) models.

Results and discussion

The estimates of different genetic components of generation mean in three, six and best fit model for ten characters of four crosses in castor are furnished in table 1 The results are elaborated cross wise for 10 characters. The results of joint scaling test with least source technique of the mean data of different traits revealed the importance of epistasis. It was inferred that, simple additive-dominance three parameter model was adequate for number of nodes upto primary spike in cross 2 and for 100 seed weight in cross 4. For other characters in the four crosses, simple additive dominance model exhibited lack of good fit. For days to 50% flowering, joint scaling test revealed the inadequacy of simple additive-dominance model in all the crosses, indicating the prevalence of inter allelic interactions. In cross 2 and 3 sequential fit four parameter model was m, [d], [i] and [j] and m, [d], [j] and [l], respectively. The magnitude of additive component was higher in all cross combinations except in cross 1. Among the epistatic interactions, [i], [j] and [l] were found significant. In case of days to maturity, none of the crosses exhibited good fit for additive-dominance model conferring the influence of epistatic interaction. The search of best fit scheme, indicates four parameters for cross 1 (m, [d], [i] and [j]), cross 3 (m, [d], [j] and [l]) and cross 4 (m, [d], [h] and [i]), while three parameter sequential fit model was indicated for cross 2 (m, [d] and [i]). The role of both additive and dominance components were important for this character.

In all the four crosses prevalence of epistatic interactions was deciphered for the character plant height. Under joint scaling test, near best fit model was obtained for cross 3 wherein m, [d], [h], [i] and [l] genetic components were significant. Four parameter best fit model was indicated for crosses 1 and 2 where the genetic components, m, [d], [i] and [j] were significant in both crosses, while for cross 4 three components, m, [d] and [j] were significant. Simple additive-dominance model was adequate for number of nodes upto primary spike in cross 2, inferring the absence of non-allelic interactions. The best fit five parameter model was obtained for cross 3, wherein, the genetic components, m, [d], [h], [i] and [l] were prevalent. In cross 4 sequential fit four parameter model was found significant, whereas in cross 1 the best fit model was, m, [d] and [j]. The magnitude of additive effect was higher for this trait. For primary spike length, none of the crosses exhibited good fit for additive-dominance model inferring the role of epistatic interactions. Under sequential fit model scheme, cross 3 exhibited near best fit of five parameter (m , [d], [h], [i] and [l]) while for cross 4 three genetic components viz., m, [d] and [j] were important. The interference of higher order of epistasis and/or linkage was expected in the expression of this in two crosses (1 and 2). The magnitude of dominance effect was higher than that of additive for this trait.

In adequacy of three parameter model indicating the role of epistatic gene effects was noticed for effective spike length in all the four crosses studied. Sequential fit five parameter model observed in cross 1 was, m, [d], [h], [i] and [l], while in cross 2, it was m, [h], [i], [j] and [l]. In cross 3, four parameter sequential fit model, m, [d], [h] and [i] was observed. Three genetic parameters (m, [d] and [j]) were important for effective spike length in cross 4. The magnitude of dominance effect was higher than that of additive for this trait.Regarding number of capsules/primary spike, evidence of epistatic effects was noticed due to inadequacy of 3-parameter model. In cross 2 sequential fit five parameter was the best fit with the significant genetic parameters viz., m, [d], [h], [i] and [l]. Whereas in cross 1, four parameters viz., m, [d], [j] and [l] were important. Crosses 3 and 4 showed best fit of m, [d] and [i] and m, [d] and [l] type of gene actions, respectively with in a desired direction. In general, the magnitude of the dominance was found to be higher than additive component for this character.

For the character, 100 seed weight, cross 4 only exhibited simple additive-dominance model, whereas in other three crosses sequential fit models were best fit indicating the prevalence of non-allelic interactions. For cross 1, near best fit model was five parameter with the genetic parameters, m, [d], [h], [i] and [l], while for the cross 2, best fit model was the two parameter model where m and [d] were important. In case of cross 3, none of the model showed adequacy for 100 seed weight, indicating the involvement of higher order of epistasis or linkages.Non-allelic gene interactions were deciphered for seed yield/plant. Sequential fit model of five parameter, m, [d], [h], [i] and [l] (cross 2), m, [h], [i], [j] and [l] (cross 3) and m, [d], [h], [i] and [j] (cross 4) were found to be important. While cross 1 showed adequacy to the near best fit model of three parameter, wherein, dominance and additive × dominance type of gene interactions were prevalent for seed yield/plant. The magnitude of dominance was higher in magnitude than additive component in all the crosses studied.

For oil content, the inadequacy of three parameter model was noticed for the two crosses studied. In cross 3 and 4 scaling test and genetic components were not carried out as there were non-significant results in analysis of variance. For this trait, sequential fit model of m, [d], [h], [j] and [l] were proved to be important in cross 1, while for cross 2, the best fit model was four parameter, where the genetic components m, [d], [h] and [l] found to be significant. The presence of epistatis was reported for all the characters studied in the present investigation viz., days to 50% flowering, days to maturity, plant height, number of nodes upto primary spike, primary spike length, effective spike length, number of capsules/primary spike, 100 seed weight, seed yield/plant and oil content by Pathak *et al.* (1988), Gondaliya *et al.* (2001), Solanki *et al.* (2003) and Golakia *et al.* (2004). In the present study, the three parameter model i.e., m, [d] and [h] was satisfactory to detect the genetic differences in cross 2 for number of nodes upto primary spike and cross 4 for 100 seed weight suggesting that there is no role of epistasis. Dobariya *et al.* (1992) reported similarly.

In the present study, magnitude of [d] was relatively small to that of other gene effects. Thus, additive gene is playing a minor contribution to the inheritance of these traits. The relative magnitude of the genetic parameter [d] was important for days to 50% flowering (cross 2 and 3), days to maturity (cross 2, 3 and 4), plant height (cross 4), number of nodes upto primary spike (cross 1, 2 and 4), primary spike length (cross 4), effective spike length (cross 4) and 100 seed weight (cross 2). Thus, it could be easier to select and isolate high performing inbred lines for these traits in early generations. Hence, selection for transgressive segregants in the early generations would be more effective for obtaining genetic gain of these characters. In majority of the characters, the dominance gene action is playing a major role as compared to additive gene actions. The importance of dominance gene effects was indicated not only by its significance and relative magnitude by its sign. Positive dominance gene effects suggests its enhancing effect on the performance of different traits. However, for days to 50% flowering and days to maturity in cross 4, dominance gene effects possessed negative sign, indicating that dominance was in the direction of early maturity. In comparison to additive gene effect, dominant gene effects were more important for primary spike length and effective spike length (cross 1, 2 and 3), number of capsules per primary spike (cross 2), 100 seed (cross 1 and 3), seed yield/plant (cross 1, 2, 3 and 4) and oil content (cross 2).

Considering the significance of epistatic interaction, it was revealed that the characters viz., days to 50% flowering (cross 1, 3 and 4), days to maturity, plant height and number of nodes upto primary spike (cross 3), primary spike length and seed yield/plant (cross 2 and 3), effective spike length and oil content (cross 1 and 2), number of capsules/primary spike (cross 1, 2 and 4) and 100 seed weight (cross 1 and 3) were influenced by dominance × dominance [l] type of gene interactions in one cross or the other.In the complementary type of gene, interaction particularly [i] and [l] reinforce the effect of dominance, while in the duplicate type of interaction, they oppose the effect of the dominance component. In the present study none of the characters of four crosses exhibited complementary type of epistasis similar findings were reported by Gondaliya *et al.* (2001) and Golakia *et al.* (2004) Solanki *et al.* (2003).

Table 1 Estimates of gene effects for different characters in four crosses of castor

Parameter	Days to 50% flowering	Days to maturity	Plant height	Number of nodes upto primary spike	Primary spike length	Effective spike length	No. of capsules/ primary spike	100 seed weight	Seed yield/plant	Oil content
Kranthi x RG-224 (cross 1)										
m	55.35**	117.59**	81.87**	13.55**	41.11**	37.91**	55.11**	27.90**	208.48**	50.4**
[d]	-12.26**	-12.88**	-29.90**	-1.91**	-4.42**	-5.17**	-15.66**	0.44**	-7.25**	2.42**
[h]	5.73**	4.37**	-16.97**	-1.33**	6.92**	6.33**	24.60**	2.98**	106.79**	0.53**
χ^2-3	289.61**	102.34**	246.29**	23.53**	40.04**	17.79**	122.42**	22.54**	22.88**	64.25**
m	58.01**	121.26**	90.29**	13.50**	33.81**	21.57**	55.96**	20.00**	186.94**	46.26**
[d]	-11.44**	-12.46**	-27.79**	-1.56**	-3.66**	-5.17**	-14.63**	0.44**	-	2.21**
[h]	-	-	-	-	15.87**	38.26**	-	18.86**	133.50**	-28.56**
[i]	-2.29**	-3.83**	-10.15**	-	8.35**	16.68**	-	8.00**	-	-
[j]	-23.43**	-20.25**	41.09**	-5.80**	-7.31**	-	-15.35**	-	-49.87**	7.61**
[l]	3.68**	-	-	-	-	-14.91*	20.56**	-7.81**	-	16.58**
χ^2 (6-p)	19.11**	4.31 NS	1.51 NS	0.20 NS	5.95*	3.96 NS	0.03 NS	2.44 NS	1.04 NS	1.69 NS
Non-allelic interaction	-	-	-	-	-	D	-	D	-	D
DPC-9 x RG-2374 (Cross 2)										
m	52.50**	120.69**	69.58**	13.56**	49.33**	42.15**	53.06**	27.65**	204.22**	52.52**
[d]	3.35**	4.64**	-3.40**	0.66**	-1.29**	-0.75	3.54**	2.74**	25.11**	-0.77**
[h]	-5..39**	-9.03**	-27.14**	-4.15**	-8.25**	-4.48**	8.50**	5.78**	39.38**	6.78**
χ^2-3	136.98**	123.62**	53.10**	1.26 NS	49.25**	101.74 **	27.74**	12.38**	118.32**	23.10**
m	63.38**	132.71**	49.03**	-	31.23	30.46**	48.62**	27.94**	70.55**	48.74**
[d]	3.33**	4.55**	-3.62**	-	-1.09**	-	3.20**	2.77**	25.57**	-1.21**
[h]	-	-	-	-	95.14**	81.60**	119.89**	-	267.86**	6.56**
[i]	-11.62**	-12.60**	21.02**	-	49.45**	42.51**	53.06**	-	143.68**	-
[j]	-2.66*	-	13.64**	-	-	-11.63**	-	-	-	-
[l]	-	-	-	-	-53.81**	-43.07**	-58.43**	-	-78.96**	-9.04**
χ^2(6-p)	0.90 NS	4.38 NS	0.97 NS	-	4.88*	1.94 NS	0.11 NS	2.12 NS	3.33 NS	2.59 NS
Non-allelic interaction	-	-	-	-	D	D	D	-	D	D
VP-1 x RG-1719 (Cross 3)										
m	57.38**	121.88**	50.34**	14.55**	54.42**	57.38**	121.88**	50.34**	14.55**	54.42**
[d]	3.07**	-2.31**	-13.70**	1.28**	8.36**	3.07**	-2.31**	-13.70**	1.28**	8.36**
[h]	-12.57**	-14.30**	-2.74**	-2.63**	-3.89**	-12.57**	-14.30**	-2.74**	-2.63**	-3.89**
χ^2-3	26.06**	143.28**	40.40**	17.71**	100.32**	26.06**	143.28**	40.40**	17.71**	100.32**
m	53.61**	121.10**	44.32**	22.29**	14.79*	53.61**	121.10**	44.32**	22.29**	14.79*
[d]	3.26**	-1.63**	13.79**	1.30**	8.42**	3.26**	-1.63**	13.79**	1.30**	8.42**
[h]	-	-	113.65**	-18.40**	61.49**	-	-	113.65**	-18.40**	61.49**
[i]	-	-	50.13**	-7.83**	40.15**	-	-	50.13**	-7.83**	40.15**
[j]	-9.00**	-15.03**	-	-	-	-9.00**	-15.03**	-	-	-
[l]	-8.88**	-18.38	-66.38**	7.84*	-24.54**	-8.88**	-18.38**	-66.38**	7.84*	-24.54**
χ^2(6-p)	0.07 NS	2.00 NS	2.25 NS	0.71 NS	2.39 NS	0.07 NS	2.00 NS	2.25 NS	0.71 NS	2.39 NS
Non-allelic interaction	-	-	D	D	D	-	-	D	D	-
LRES-17 x RG-1471 (Cross 4)										
m	48.11**	106.81**	33.19**	10.04**	34.53**	48.11**	106.81**	33.19**	10.04**	34.53**
[d]	4.67**	5.74**	-2.04**	1.73**	11.96**	4.67**	5.74**	-2.04**	1.73**	11.96**
[h]	-5.48**	-6.13**	9.61**	-1.92**	-1.53	-5.48**	-6.13**	9.61**	-1.92**	-1.53
χ^2-3	26.86**	22.04**	27.31**	15.32**	54.88 **	26.86**	22.04**	27.31**	15.32**	54.88 **
M	58.68**	113.55**	32.63**	11.96**	23.06**	58.68**	113.55**	32.63**	11.96**	23.06**
[d]	4.66**	5.80**	-1.56**	1.79**	11.59**	58.68**	5.80**	-1.56**	1.79**	11.59**
[h]	-31.84**	-13.78**	-	-4.07**	-	-31.84**	-13.78**	-	-4.07**	-
[i]	-10.38**	-7.13**	-	-2.11**	-	-10.38**	-7.13**	-	-2.11**	-
[j]	-	-	-12.86**	-	11.76**	-	-	-12.86**	-	11.76**
[l]	16.29**	-	-	-	-	16.29**	-	-	-	-
χ^2 (6-p)										
Non-allelic interaction	D	-	-	-	-	-	-	-	-	-

Note : p- refers to the number of **parameters included and eliminated** for anlaysis; * = *Significant at 5% and* ** = *Significant at 1% level*; NS = Nonsignificant *and D=Duplicate* epistasis

Besides additive, epistatic component of additive × additive [i] significance indicates the preponderance of additivity over non-additivity. In the present study *viz.*, days to 50% flowering and days to maturity (cross 1, 2 and 4), plant height, primary spike length and effective spike length (cross 1, 2 and 3), number of nodes upto primary spike (3 and 4), number of capsules/primary spike (cross 2 and 3), 100 seed weight (cross 1 and3) and seed yield/plant (cross 2, 3 and 4) and these interactions would enhance the chances for making improvement through selection (Solanki *et al.*, 2003) in castor. The epistatic component of additive × dominance [j] gene effects were of minor importance in general and observed in certain crosses for days to 50% flowering (cross 1, 2 and 3), days to maturity (cross 1 and 3), plant height (cross 1, 2 and 4), number of nodes upto primary spike, number of capsules/primary spike and oil content (cross 1), primary spike length (cross 1 and 4), effective spike length (cross 2 and 4) and seed yield/plant (cross 1, 3 and 4). Pathak *et al.* (1988), Gondaliya *et al.* (2001), Solanki *et al.* (2003) and Golakia *et al.* (2004) also reported similarly.

In the present investigation, in majority of the cases, sequential model schemes were found best fit which have two important advantages. Firstly, it increases the precision with which the remaining parameters are estimated after the elimination of non-significant components and secondly it provides more degree of freedom for and χ^2 test (Mather and Jinks, 1982). Thus, epistasis is the integral part of genetic architecture of the present material used in the investigation and breeder cannot ignore it. The six genetic parameters estimated provide a test for different types of gene action and are useful in giving information for the improvement of these traits. The presence of dominance and epistatic effects for different traits in all the crosses would slow down the progress of selection. Hence, it is suggested that the use of intermating of selector followed by visual selection in early segregating generations would simultaneously exploit both types of gene effects.

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Genetic variability, character association and path analysis of yield and its component traits in castor, *Ricinus communis* L.

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Abstract

Genetic variability, character association and path analysis between yield and its component traits were carried out in 95 genotypes of castor. Highly significant differences among the genotypes were recorded for all the characters studied. The estimates of genotypic and phenotypic variances indicated the presence of wide range of variation for seed yield and its components. The PCV and GCV were highest for plant height followed by effective spike length, seed yield/plant, number of capsules/primary spike and primary spike length. Maximum value of heritability was recorded in 100 seed weight followed by days to 50% flowering, days to maturity, plant height and seed yield/plant revealing additive gene action for these traits. The traits *viz.*, plant height, number of capsules/primary spike, seed yield/plant and effective spike length can be successfully improved by direct selection as they possess high heritability coupled with high genetic advance. The results of the correlation indicated that primary spike length, effective spike length and number of capsules/primary spike are the important productive yield components as they had strong and positive association with seed yield/plant. Path analysis revealed that yield can be increased by improving characters like effective spike length, number of capsules/primary spike and 100 seed weight as these showed a high and positive direct effect and significant correlation with seed yield/plant.

Keywords: GCV, PCV, heritability, correlation, path analysis, castor

Introduction

Development of high yielding cultivars requires knowledge of the existing genetic variation and also the extent of association among the yield contributing characters. The coefficient of variation expressed in phenotypic and genotypic levels is used to compare the variability observed among different characters. The observed variability is a combined estimate of genetic and environmental causes of which only the former one is heritable. The heritability estimated aids in determining the relative amount of heritable portion in variation and thus helps the plant breeder in selecting elite lines from diverse population. However, the estimate of heritability alone does not provide an idea of the expected gain in the next generation but it has to be considered in conjunction with genetic advance. Character association and path analysis will establish the extent of association between yield and its components and also bring out the relative importance of their direct and indirect effects, thus giving a clear understanding of their association with yield. The present study deals with the above genetic constant and character association for eleven characters in 95 genotypes of castor.

Materials and methods

The experimental material of comprised 95 genotypes (20 parents and 75 F_1s) of castor. The field experiment was laid out in a randomized block design with three replications at College Farm, College of Agriculture, Rajendranagar, Hyderabad during the rainy season of 2006. Each cross was sown in two rows of 5 m length with a spacing of 90 cm x 60 cm. All the standard agronomic and plant protection measures were followed to grow a healthy crop. The data were recorded on five random plants for each treatment in each replication for ten morphological characters *viz.*, days to 50% flowering, days to maturity, plant height, number of nodes upto primary spike, primary spike length, effective spike length, number of capsules/primary spike, 100 seed weight, oil content and seed yield/plant. Mean values for different traits were used for statistical analysis. The genotypic (GCV) and phenotypic (PCV) coefficients of variability were computed as per Burton (1952), heritability as per Falconer (1981) and the phenotypic and genotypic variances and genetic advance were computed following Johnson *et al.* (1955). Genotypic correlation coefficients were worked out following Al-Jibouri *et al.* (1958) and path coefficient analysis following the method of Dewey and Lu (1959).

Results and discussion

The analysis of variance recorded highly significant differences between genotypes for all the characters studied. There is considerable amount of inter-varietal variability in castor. The estimates on phenotypic range, genotypic and phenotypic variances, genotypic and phenotypic coefficient of variability, heritability and genetic advance are presented in table 1. The results revealed the presence of wide range of phenotypic variation for seed yield/plant and its important components *viz.*, plant height, number of capsules/primary spike, effective spike length, primary spike length, days to maturity, days to 50% flowering and 100 seed weight which would facilitate greater options for selection of desirable and ideal genotypes from the experimental material and hence would provide greater chances of success in breeding programme. Patel *et al.* (2004), Dhapke *et al.* (1992), Mehta and Vashi (1997) and Sevugaperumal *et al.* (1999) also observed wide phenotypic range for seed yield/plant and important yield components.

In general, the phenotypic coefficients of variability were higher than the corresponding genotypic coefficients of variability for various characters studied, indicating the marked influence of environment in the expression of these characters. The PCV and GCV were highest for plant height followed by effective spike length, seed yield/plant, number of capsules/primary spike and primary spike length suggesting that these characters are under the influence of genetic control. Hence these characters can be improved by simple selection. The difference between PCV and GCV was minimum for days to 50% flowering, days to maturity and 100 seed weight suggesting that these traits were least affected by environment. This observation draws support from the very high value of heritability [>95 recorded for these traits (Table 1)].

High estimates of heritability in broad sense were observed for all the characters studied. Maximum value was recorded in 100 seed weight followed by days to 50% flowering, days to maturity, plant height and seed yield/plant revealing additive gene action for these traits. Hence the improvement of these traits can be made through direct phenotypic selection. Johnson *et al.* (1955) suggested that heritability estimates along with genetic advance would be more useful in predicting yield under phenotypic selection than heritability estimates alone. Characters having high heritability with wider variability and high genetic advance as per cent of mean generally indicate the lesser influence of environment and predominance of additive gene action in their inheritance and hence these traits would be successfully improved by direct selection (Panse, 1957). In the present investigation, such type of conclusion can be obtained for plant height, number of capsules/primary spike, seed yield/plant, effective spike length.

The traits with high heritability and low genetic advance and those with low heritability and high genetic advance indicate the presence of both additive and non-additive gene action with the preponderance of the latter. This indicates the environmental influence on these traits in considerable amounts. This holds true in case of oil content and days to maturity. High heritability might be based on favourable influence of environment and hence selection for these traits may not be rewarding. Similar results were reported by Patel *et al.* (2004).

Yield is a complex character and an outcome of the interaction of all the other characters. Such characters are highly influenced by environment. Therefore direct selection for this trait will not be useful. Initially it would be better to improve the component traits and selection for high yield could be practiced later in generations when considerable amount of homozygosity has been achieved in the families. The association between different characters and their combinations studied in castor both at genotypic and phenotypic levels have been presented in table 2.

Seed yield/plant exhibited significant and positive correlation with days to maturity, number of nodes upto primary spike, primary and effective spike length, number of capsules/primary spike, 100 seed weight and oil content both at phenotypic and genotypic levels. It exhibited a positive but non-significant association with days to 50% flowering and plant height. Among the component characters days to 50% and days to maturity were similarly associated with number of nodes upto primary spike, primary spike length and effective spike length exhibiting significant positive value while with 100 seed weight both traits showed non significant negative association. The traits days to maturity and number of nodes upto primary spike showed and significant and positive correlation with seed yield/plant indicating the importance of late maturity and high node number for increased seed yield/plant. The observations of Vindhiyavarman and Manoharan (1994), Aswanikumar *et al.* (2003), Patel *et al.* (2004) and Yashpalyadav *et al.* (2004) were in agreement with the present findings.

Plant height and number of nodes upto primary spike had significant and positive association with primary spike length, effective spike length, number of capsules/primary spike. Among the important yield contributing characters, primary spike length, effective spike length, number of capsules/primary spike had strong positive association with seed yield/plant and also among themselves. The results indicated that these component traits are productive for increase in seed yield as reported by Mehta and Vashi (1998), Raghuramreddy *et al.* (2000), Rameshthatikunta and Durgaprasad (2001) and Aswanikumar *et al.* (2003).

Hundred seed weight had negative relationship with all the characters studied but with seed yield/plant it was positive and significant. Primary spike length, effective spike length, number of capsules/primary spike were negatively correlated with 100 seed weight may be due to competition for photosynthates. The trait, oil content exhibited significant and positive association with 100 seed weight while it showed non-significant correlation with rest of the characters.

A study of character association will greatly help the plant breeder in making effective selection in the field. In any crop improvement programme precise selection for seed yield is necessary because of its complex nature of G x E interaction. In the present study, the results indicated that the genotypic and phenotypic correlation followed the same trend and in general the values of genotypic were higher than those of phenotypic correlation coefficients for all the characters studied indicating there by less role of environment. Thus, primary spike length, effective spike length and number of capsules/primary spike are the important productive yield components as they had strong and positive association with seed yield/plant. These characters were also correlated among themselves. Hence, during selection emphasis must be laid on the above said traits, which provide simultaneous improvement of seed yield.

Yield is the sum total of the several component characters which directly or indirectly contributed to it. The information derived from the correlation studies indicated only mutual association among the characters. Whereas, path coefficient analysis helps in understanding the magnitude of direct and indirect contribution of each character on the dependent character like seed yield. The path coefficient analysis of yield components and their effect on seed yield are presented in table 3. The estimated residual effect 0.121 indicates the adequacy and appropriateness of the characters chosen for path analysis. Direct effect of days to flowering on seed yield was negative indicating the necessity for early flowering. Number of nodes upto primary spike also showed indirect negative effect on seed yield. Patel and Jaimini (1991) and Rameshthatikunta and Durgaprasad (2001) opined the importance of early flowering in castor.

Plant height exhibited a positive genotypic correlation with seed yield. The direct effect of plant height and indirect effect via number of nodes upto primary spike were negative indicating the need for short stature plant types. Number of nodes upto primary spike and seed yield/plant exhibited a positive and significant genotypic correlation. The direct effect of this trait and indirect effect of days to 50 % flowering and plant height was negative underlying the need for short plant types. Such type of negative relationship was also reported by Dorairaj *et al.* (1973). Primary spike length which showed a strong and positive association with seed yield/plant gave negative direct effect. This was due to indirect influence via effective spike length and number of capsules/primary spike. On the contrary, oil content which showed significant positive association with seed yield/plant exhibited negative direct effect.

Effective spike length showed significant correlation with a positive direct effect on seed yield. Similar positive association was previously reported by Khorgade *et al.* (1994). However, plant height and number of nodes upto primary spike showed indirect negative effect indicating the necessity of dwarf and early flowering plant type to attain longer main spikes. Number of capsules/primary spike had significant correlation and a direct positive effect on seed yield/plant. Primary spike length and 100 seed weight showed negative indirect effect indicating that contribution of capsules needs to be ensured for increase in seed yield/plant.

Hundred seed weight showed significant and direct positive effect on seed yield/plant. Negative indirect effect of number of capsules/primary spike emphasizes the necessity of seed filling. Hence, selection of medium sized seeds can be used as selection criteria. Oil content had significant positive correlation with seed yield/plant but showed direct negative effect. This was due to indirect influence of effective spike length, number of capsules/primary spike and 100 seed weight on seed yield/plant. Thus it may be concluded that improvement in characters like effective spike length, number of capsules/primary spike and 100 seed weight will help in improving seed yield in castor both directly and indirectly. Therefore, these characters should be considered for yield improvement in castor breeding programme.

Table 1 Mean, range and genetic parameters for characters in castor

Characters	Mean + SE	Range		Variance		Coefficient of variability		Heritability (%)	GA (% of mean)
		Min.	Max.	Genotypic	Phenotypic	Genotypic	Phenotypic		
Days to 50% flowering	49.31+0.83	39.00	79.67	49.84	51.91	14.32	14.61	96.02	28.90
Days to maturity	110.55+1.16	89.00	139.67	93.02	97.02	8.72	8.91	95.88	17.60
Plant height (cm)	55.46+2.48	29.47	108.07	283.63	301.86	30.37	31.33	93.96	60.64
No. of nodes upto primary spike	11.22+0.48	7.40	17.53	4.27	4.94	18.41	19.80	86.44	35.26
Primary spike length (cm)	42.92+2.02	24.40	70.07	89.34	101.47	22.02	23.47	88.04	42.57
Effective spike length (cm)	35.30+2.16	13.60	63.27	113.78	127.59	30.14	31.91	89.18	58.62
No. of capsules/primary spike	47.58+3.15	25.80	88.60	150.31	179.73	25.77	28.18	83.63	48.54
100 seed weight (g)	32.97+0.63	18.77	52.00	33.80	34.98	17.63	17.94	96.62	35.70
Oil content (%)	49.50+0.58	42.79	52.76	2.96	3.97	3.48	4.03	74.47	6.18
Seed yield/plant (g)	203.98+9.48	90.96	325.47	3071.39	3338.15	27.17	28.32	92.01	53.68

Table 2 Genotypic and phenotypic correlation coefficients for seed yield and its components in castor

Character		Days to 50% flowering	Days to maturity	Plant height	No. of nodes up to primary spike	Primary spike length	Effective spike length	No. of capsules/primary spike	100 seed weight	Oil content	Seed yield/plant
Days to 50% flowering	G	1.000	0.88**	0.776**	0.88**	0.646**	0.661**	0.676**	-0.156	-0.128	0.136
	P	1.000	0.85**	0.732**	0.809**	0.589**	0.612**	0.609**	-0.148	-0.109	0.131
Days to maturity	G		1.000	0.762**	0.836**	0.639**	0.666**	0.725**	-0.071	-0.052	0.233*
	P		1.000	0.72**	0.763**	0.592**	0.623**	0.657**	-0.066	-0.047	0.219*
Plant height	G			1.000	0.791**	0.557**	0.521**	0.603**	-0.104	-0.158	0.122
	P			1.000	0.727**	0.515**	0.484**	0.558**	-0.099	-0.132	0.124
No. of nodes upto primary spike	G				1.000	0.721**	0.751**	0.712**	-0.216*	-0.058	0.224*
	P				1.000	0.636**	0.672**	0.634**	-0.194	-0.070	0.209*
Primary spike length	G					1.000	0.935**	0.73**	-0.103	0.040	0.456**
	P					1.000	0.898**	0.657**	-0.087	0.038	0.429**
Effective spike length	G						1.000	0.828**	-0.080	0.052	0.483**
	P						1.000	0.738	-0.072	0.038	0.448**
No.of capsules/primary spike	G							1.000	-0.055	0.021	0.646**
	P							1.000	-0.039	-0.012	0.579**
100 seed weight	G								1.000	0.426**	0.422**
	P								1.000	0.363**	0.406**
Oil content	G									1.000	0.329**
	P									1.000	0.257*
Seed yield/plant	G										1.000
	P										1.000

* Significant at 5% level, ** Significant at 1% level

Table 3 Direct (diagonal and bold) and indirect effects of path coefficients based on genotypic correlation in castor

Characters	No. of spikes/ plant	Days to 50% flowering	Days to maturity	Plant height	No. of nodes upto primary spike	Primary spike length	Effective spike length	No. of capsules/ primary spike	100 seed weight	Oil content	Correlation with seed yield/plant
Days to 50% flowering	-0.236	**-0.061**	0.084	-0.010	-0.271	-0.113	0.204	0.610	-0.072	0.001	0.136
Days to maturity	-0.257	-0.054	**0.095**	-0.009	-0.257	-0.112	0.206	0.654	-0.033	0.000	0.233*
Plant height	-0.208	-0.048	0.073	**-0.012**	-0.243	-0.098	0.161	0.544	-0.048	0.001	0.122
No. of nodes upto primary spike	-0.133	-0.054	0.080	-0.010	-0.308	-0.126	0.232	0.642	-0.100	0.001	0.224*
Primary spike length	-0.061	-0.040	0.061	-0.007	-0.222	**-0.176**	0.289	0.658	-0.048	0.000	0.456**
Effective spike length	-0.157	-0.040	0.063	-0.006	-0.231	-0.164	**0.309**	0.747	-0.037	0.000	0.483**
No. of capsules/primary spike	-0.160	-0.041	0.069	-0.007	-0.219	-0.128	0.256	**0.902**	-0.025	0.000	0.646**
100 seed weight	-0.050	0.010	-0.007	0.001	0.067	0.018	-0.025	-0.049	**0.461**	-0.004	0.422**
Oil content	0.090	0.008	-0.005	0.002	0.018	-0.007	0.016	0.019	0.197	**-0.009**	0.329**

Residual effect= 0.121

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Sources of resistance to biotic stresses in castor : An overview

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Abstract

Castor (*Ricinus communis* L.) is an important oil yielding plant with lot of export potential and India is the world's largest producer contributing to 73.2% of world production. Biotic stresses occurring in the crop play a key role in affecting the average productivity of castor. The most appropriate way of tackling these pests is developing resistant cultivars by introgressing resistant genes from the established resistant genotypes. Globally, there are about 12 major sources of castor germplasm collections identified by the International Germplasm Repositories *viz.*, Bioversity International and the USDA-ARS castor germplasm at Griffin, GA (USA) with total collections of 6588 accessions. The present paper reviewed the progress made so far in castor towards identification of resistant sources against important diseases *viz.*, root rot (*Macrophomina phaseolina*), *Fusarium* wilt (*Fusarium oxysporum* f. sp. *ricini*), grey mould (*Botrytis ricini*), defoliator insects (castor semilooper, hairy caterpillar and tobacco caterpillar etc), leaf miner (*Liriomyza trifoli*), sucking pests (jassids, and whiteflies) and nematodes (*Rotylenchulus*

reniformis). Global efforts made so far in identifying multiple resistance against diseases have also been reviewed in the present article, while indicating progress made in the development of transgenic material in castor.

Keywords: *Ricinus communis,* insect pests, diseases, nematodes, resistance, tolerance

Introduction

Castor (*Ricinus communis* L.), a member of Euphorbiaceae is a tropical plant that is grown for its non-edible oilseed. The oil obtained from the seeds of this plant is a very useful raw material in many industries like soap, surface coatings, cosmetics, pharmaceuticals, perfumes, greases and lubricants etc. The seeds generally contain 48% oil content and the rest becomes the part of oil cake.

Diseases and insect pests play an important role in the production of castor seed. Castor is vulnerable to the attack of several biotic stresses, which include 93 fungal species, 6 bacteria, 1 phenerogamic parasite, 23 nematode species and several insect species (Purdue Univ, 1983). On an average, the damage is over 70% due to these pests and diseases. In India, 11 fungal species, 3 bacteria, 2 viruses, 2 nematodes, 41 insect species and 6 weed species are known to attack castor (CABI, 2005). Of these, wilt (*Fusarium oxysporum* f. sp. *ricini*), root rot (*Macrophomina phaseolina*) and grey rot (*Botrytis ricini*) are major diseases of castor that can cause upto 80-100% crop damage (Anjani *et al.*, 2004). The bacterium, *Rhizobium rhizogenes* (gall) is designated as quarantine pest in India (Plant Quarantine Order, 2003) and as a consequence castor seed imported from USA has to be checked thoroughly for the presence of this bacterium. The most appropriate way of tackling these pests is developing resistant cultivars by introgressing resistant genes from the resistant sources (Anjani, 2005). The present paper gives a review on the globally available resistant sources for castor pests so as to utilize them in the ongoing and future breeding programmes.

Globally, there are about 12 major sources of castor germplasm collections identified by International germplasm collections on the Bioversity web site combined with the USDA-ARS castor germplasm at Griffin, GA (USA) with total collections of 6588 accessions (Auld *et al.*, 2009). Eventhough as per the Bioversity web site, there are only 290 Indian accessions, known to have been collected by NBPGR Regional Station located in Akola, presently the National Gene Bank at New Delhi, India has a total collection of 2611 accessions of castor, collected from different states of India (NORV database). Apart from India, extensive germplasm collections are held in Brazil, China, Ethiopia, Kenya and the former USSR, but availability of these germplasm resources is not clearly known. Castor germplasm can be obtained from public breeders in South America including Brazil and Columbia. In tropical climates world wide, castor can be found as an introduced plant species surviving as a weed in roadsides and non-cultivated areas. This castor can be a valuable source of germplasm especially for adaptation to localized diseases, pests and environmental conditions.

Castor researchers worldwide are concentrating on its genetic improvement for high productivity coupled with resistance to major diseases and insect pests to make it competitive with other vegetable oils in energy market. Thus, new sources of disease and pest resistance are in constant demand by the breeders. Ricinus is a monotypic genus and *R. communis* is the lone species encompassing several polymorphic types known in the world (Weiss, 1983). Several of these types though were designated as different species (*R. communis; R. macrocarpus* and *R. microcarpus*), they were found fertile, intercrossable and therefore are not true species. Success of breeding in castor with yield stability is thus limited due to lack of exploitable genetic variability for productivity traits and sources of resistance to pests and diseases. Thus breeders have to depend upon alternative approaches such as intergeneric hybridization, mutation and biotechnology for the creation of genetic variability and incorporation of desired traits into castor (Sujatha, 2008). The status on globally available pest resistant sources of castor is reviewed below:

Diseases

Root rot: Root rot caused by *Macrophomina phaseolina* is one of the most destructive diseases of castor crop in the dryland areas of India. A long dry spell with high temperature favours this disease. There are about 20 known sources of resistance to root rot of castor, which include germplasm, varieties and hybrids. Of the 19 accessions identified as resistant to root rot at Gujarat Agricultural University, Junagadh, 17 (RG 2706 to RG 2734) were collections from Andaman and Nicobar Islands of India (Anjani *et al.*, 2004). RG-392 accession, which was found moderately resistant earlier, showed resistant reaction in 2004 (Anjani *et al.*, 2004). Macêdo Vieira *et al.*, (1998) identified two lines *viz.*, CNPA M. 90-210 and CNPA M. SM4 from Brazil resistant to root rot caused by *M. phaseolina* and *Botryodiplodia theobromae*.

Wilt: Wilt caused by *Fusarium oxysporum* f. sp. *ricini* is the most important soil and seed-borne disease of castor in India. *Fusarium* wilt incidence as high as 85-90% was reported in wilt-endemic areas of various castor-growing states. It causes yield loss to the extent of 60-70%. Thus most of the castor breeders in India focused their research on this disease and made enough progress in finding out the resistant sources (Anjani, 2003a ; Golakia *et al.*, 2003; Anjani *et al.*, 2004). The breakdown of wilt resistance in resistant sources like GCH-4 (Patel *et al.*, 1991), DCS-9 (Anjani *et al.*, 2004) indicate the need for continuous search of resistant sources for crop improvement.

Genetic diversity among 20 identified wilt resistant castor germplasm was assessed using multivariate classificatory methods (Anjani, 2010). Wide genetic diversity was demonstrated among these accessions, which would serve as base diverse material for wilt resistance breeding, wilt resistant genepool construction and molecular markers. The diverse resistant accessions would have perpetual value for scientific advancement in host-plant resistance breeding in castor. They are also promising sources for molecular characterization, tagging and mapping of wilt resistance genes in castor for utilization in marker assisted breeding. Desai *et al.* (2001) studied the genetics of wilt resistance and found that the inheritance of resistance was governed by polygenes showing dominance.

Grey mould: All the existing castor varieties and hybrids are susceptible to grey rot and non-genetic measures have failed to control it. Screening of 145 accessions against grey rot under artificial epiphytotic conditions resulted in identification of six resistant accessions (RG-2694, 2718, 2724, 2731, 2732 and 2733), which were collections from the Andaman and Nicobar Islands (Anjani *et al.*, 2004). Use of non-spiny varieties with less compact inflorescence is preferred to combat the disease incidence. Sunil *et al.*, (2005) identified 10 such accessions from Andhra Pradesh with non-spiny and loose spikes as probable sources of resistance to grey rot.

In addition to the above, very few sources of resistance were identified earlier (Table 2) against rust (*Melampsora ricini*), leaf spot (*Alternaria ricini*) and bacterial leaf spot and blight (*Xanthomnas campestris* pv *ricini* and *Xanthomonas ricinicola*). Castor varieties that are susceptible to damping-off (*Rhizoctonia solani*) and bacterial wilt (*Ralstonia solanacearum*) are also indicated (Table 2).

Insect pests

The crop is infested by number of insect pests, among which defoliators, *viz.*, leaf miner (*Liriomyza trifolii*), semilooper (*Achoea janata*) and tobacco caterpillar (*Spodoptera litura*) are important. Average crop losses due to insect pests *viz.*, semilooper, capsule borer, jassids, and whitefly were estimated to be 20.1% (Ramanathan, 2004). The resistant sources against insect pests are listed in table 3.

Serpentine leaf miner (*Liriomyza trifolii*): This pest is assuming importance on castor these days due to its wide host range, low sensitivity to insecticides and ability to survive and multiply over wide range of seasonal conditions. In India, it was first recorded on castor during rainy season in 1991 (Lakshminarayana *et al.*, 1992). Some sources of resistance to leaf miner were identified (Anjani, 2003b and Anjani *et al.*, 2009). Recently, 12 varieties were identified as resistant to this pest in Karnataka (Hegde *et al.*, 2009). In general, castor plants with 'papaya' leaf types showed resistance to leaf miner. The plant with red stem and single, double and triple blooms showed resistance to leaf miner and semilooper. Castor plants with spiny and compact spikes carried high shoot and capsule borer infestation than those with spineless/ non-spiny and loose spikes (Hegde *et al.*, 2009). Significant relation between high total phenol concentrations in dark purple leaf phenotype and leaf miner resistance in castor was established as dark purple leaf progenies possessed high concentrations of total phenol and were resistant to leaf miner, while green leaf type progenies had low total phenol concentrations and were susceptible (Anjani *et al.*, 2010). Thus, it can be considered as an effective visual and reliable approach for indirect selection of leaf miner resistance.

Defoliators (Semilooper (*Achoea janata*): Bihar hairy caterpillar (*Spilosoma obliqua*), Coffee hairy caterpillar (*Euproctis fraterna*) and Tobacco caterpillar (*Spodoptera litura*)):

The defoliators (castor semilooper, tobacco caterpillar), sucking pests and capsule borer cause economic losses to rainfed castor. In addition to the traditional methods of identification of resistant sources, biotechnological studies are in advanced stage to develop transgenics against defoliators such as semilooper and tobacco caterpillar in castor (http://www.abfindia.org/ge5.html; Malathi *et al.*, 2006; Sujatha *et al.*, 2009) (Table 3). DOR Bt-1, a local isolates of *Bacillus thuringiensis* var *kurstaki* (H-3a, 3b, 3c) developed for management of castor semilooper has been registered under the trade name KNOCK W.P. for commercialization with the Central Insecticides Board, Govt. of India (NPCMT, 2010). Transgenics, expressing *cryIAb* exhibited ample resistance against the castor semilooper (Malathi *et al.*, 2006). A strain of *Bacillus thuringiensis* (Bt) isolate, *B. thuringiensis* DOR4, isolated from Indian soil samples was characterized and found to be toxic to *Achaea janata* larvae, hence can be exploited for its control (Madhusudhan *et al.*, 2008). Fusion gene (*Cry 1E-C*) harbouring npt gene for enabling plant selection on kanamycin and found highly effective against Bihar hairy caterpillar (http://www.abfindia.org/ge5.html).

Sucking pests [Whiteflies (*Trialeurodes ricini*) and jassids (*Empoasca flavescens*)]

Castor germplasm and varieties with sources of resistance/ tolerance against jassids and whiteflies are presented in table 3. The bloom (waxy coating on leaves and stem) was found to play a major role in the host-plant relationship in case of jassids and whitefly, no bloom types suffering severely from jassids, while triple bloom types are highly susceptible to whiteflies (Ramanathan, 2004). At Palem, 7 castor entries (RG-48, 76, 78, 97, 316 and 443) with green stem and triple bloom and one entry (RG-282) with red stem were found tolerant/resistant to jassids (Ramanathan, 2004). At NBPGR Regional Station, Hyderabad, 19 castor germplasm lines with triple bloom were identified as probable sources of resistance to jassids and another 25 accessions with zero bloom as probable sources of resistance to whiteflies (Sunil *et al.*, 2005).

Nematodes

Castor is prone to the attack of reniform nematode (*Rotylenchulus reniformis*), cyst nematode (*Heterodera ricini*) and root-knot nematode (*Meloidogyne* spp.), of which reniform nematode assumes utmost importance.

Reniform nematode has been found to be a predisposing factor for castor wilt (Chattopadhyay and Varaprasad, 2001), which has resulted in break down of resistance against wilt in wilt-resistant hybrids, *viz.*, GCH 4 and GCH 5 (Sangwan *et* al., 2005). Thus, now more emphasis is being given to develop resistance in castor hybrids against nematode-wilt complex. Seventeen high yielding castor hybrids, *viz.*, SHB-725, SHB-754, SHB-758, SHB-759, SHB-760, SHB-764, SHB-765, SHB-793, SHB-795, JHB-865, JHB-880, JHB-882, JHB-887, JHB-888, JHB-905, JHB-906, JHB-921 showed resistance to nematode-wilt complex both under artificial inoculation conditions and also in hot spots on farmers' fields. Efforts were made to screen castor genotypes against reniform nematode and wilt separately and combination of both these pathogens at Sardarkrushinagar. Genotypes Geetha, SKP-16, SKP-23, 106, 108, SKI 80, SKI 218, SKI 225, JI 258, and DCS 9 have been found resistant against nematode-wilt complex (Sangwan *et al.*, 2005).

Castor was reported to be resistant to *Meloidogyne thamesi* and *M. hapla* (Lear and Miyagawa, 1966). However, the varieties, Lynn, Baker 296, and Baker Hybrid 55 were not resistant to *M. javanica* and *M. incognita.* Castor roots of the above varieties were readily invaded by the root-knot larvae; however, the larvae either migrated out of the root or failed to develop (Orr and Morey, 1974). Thus, castor can be used successfully in crop rotation to reduce the root knot nematode populations.

Multiple resistance

Several castor accessions were identified with multiple resistance by castor breeders (Table 4). The purple morphotypes of castor germplasm accessions namely, RG 1930 and RG 2008, growing wild at Assam and Manipur and collected during castor germplasm exploration in north-eastern states, showed multiple resistance to Fusarium wilt and leaf miner in castor. So far these are the lone and the first reported sources. These purple-coloured morphotypes are rare and localized variants that could serve as diverse resistant sources for leaf miner and wilt disease with a distinct genetic marker, in castor improvement programmes in order to breed diverse resistant breeding cultivars (Anjani *et al.*, 2009).

Another land race (RG-2819), collected from Tamil Nadu was found to have resistance to Fusarial wilt and root rot (Anjani, 2006). RG-2787, a selection from KA37/01 germplasm collected from Tamil Nadu, has shown multiple resistance to wilt, root rot, grey rot and reniform nematode (Anjani and Raoof, 2009). Multiple resistance in two castor accessions (SKP-84 and SKP-215) against *Fusarial* wilt and reniform nematode were identified and these were used as female and male parents, respectively for the development of GCH-7, which is resistant to the wilt-nematode complex (Pathak *et al.*, 2006).

Majority of the castor resistance breeding work is confined to India against diseases and pests. Twelve castor accessions (SKP84, SKP215, RG47, RG297, RG392, RG1608, RG1771, RG1930, RG2722, RG2787, RG2819 and JI220) have been registered as resistant sources for biotic stresses with the Germplasm Registration Committee of ICAR and seed of respective accessions is conserved at National Gene Bank, New Delhi. In addition, 14 lines (CO-1, EC97708, GCH-4, JI-35, JM-6, JRR, RG78, RG389, RG452, RG2694, RG2706, RG 2731, SA-2, and SKP106) that were identified as resistant sources against different pests, are available in the National Gene Bank. Efforts should be enhanced to augment all other known resistant/tolerant lines in to the NGB from different sources. The present review indicates that the existing resistant sources are mostly from the indigenous material. Recently, NBPGR, Hyderabad has facilitated quarantine clearance of 113 imported castor accessions from USA and Nepal, meant for public and private organizations. Emphasis should be given to import castor accessions particularly from Ethiopia, Brazil and China for evaluation against biotic stresses. The identified resistant sources need to be purified and resistant genes may be identified for their potential as parental lines in breeding programmes.

Table 1 Major germplasm collections of castor as listed by Biodiversity International Directory (October 14, 2008) (Auld *et al.*, 2009)

Country	Collection agency	Accessions reported
Brazil	CENERGEN/EMBRAPA	360
Brazil	Centro Nacional de Pesquisa de Algodao (CNPA)	199
Brazil	Empresa Baiana de Desenvolvimento Agricola S.A.	528
Brazil	Instituto Agronomico de Campinas (I.A.C.)	200
China	Institute of Crop Science (CAAS)	1,689
China	Institute of Oil Crops Research (CAAS)	1,652
Ethiopia	Biodiversity Conservation and Research Institute	232
India	Regional Station Akola, National Bureau of Plant Genetic Resources (NBPGR)	290
Kenya	National Dryland Farming Research Station, Kenya	130
Kenya	National Genehank of Kenya, Crop Plant Genetic Resources Centre, KARI	43
Romania	Agricultural Research Station Teleorman	66
Russia	N.I. Vavilov All-Russian Scientific Research, Institute of Plant Industry	423
Serbia	Maize Research Institute	69
Serbia	Institute of Field and Vegetable Crops	43
Ukraine	Institute for Oil Crops	255
United States	USDA-ARS-PGRCU	364
World	39 Institutes	6588

Table 2 Sources of resistance to diseases in castor

Disease	Causal organism	Sources of resistance	Reference
Root rot	*Macrophomina phaseolina*	GCH-6-R	http://en.wikipedia.org/wiki/castor_oil_plant
		GCH-2-T	SDAU, 2009
		RG 2706 to 2734 (17 accessions); RG 297, RG 392-R	Anjani *et al.*, 2004
		Jyothi, Jwala, GCH-4, DCH-30 and SHB-145-T & R	http://www.ikisan.com/links/ap_ castorDisease%20Management.shtml
		RG-47, RG-392-MR	Anjani *et al., 1998*
Fusarial wilt	*Fusarium oxysporum* f.sp. *ricini*	GCH-5-R; GCH-6-T	http://en.wikipedia.org/wiki/castor_oil_plant
		GCH-7-R; SHB-145-R, SKP-4, 6, 13, 16, 19, 23, 42, 72, 84, 106, 108, 112, 113 and 114-R, Geeta-R	SDAU, 2009
		48-1-R, VP-1 and VI-9-S	Desai *et al.*, 2003
		DCS-9, DCH-32, DCH-30, DCH-4 and 48-1-S	Pushpavathi *et al.*, 1998
		Aruna-HS, 48-1-T	Chattopadhyay *et al.*, 1996
		Donskaya krupnolistnaya and Donskaya 7-HS	Golikov and Kolos, 2003
		TVC-31-MR	http://www.cabdirect.org/abstracts/20013030017.html
		TMVCH-MR	http://www.krishisewa.com/articles/castor.html
		Jyothi, Jwala, GCH-4, DCH-30 and SHB-145-T and R	http://www.ikisan.com/links/ap_castorDisease% 20Management.shtml
		RG 297-R	Anjani, 2003b
		RG-1608-R	Anjani, 2004
		GCH-4, Aruna-S, RG-389, RG-2048 and RG 1628-R	Anjani *et al.*, 2004
		Jyothi-R	Basappa, 2007
		GCH-4-R	Patel *et al.*, 1991; SDAU, 2009
		RG-392-T; RG-47-R	Anjani *et al.*, 1998
		JI-220-R	Golakia *et al.*, 2003
		M-619-R	Ramachandram *et al.*, 2003
		RG-45, 111, 224, 297, 398, 718, 737, 1354, 1608, 1624, 1631, 1633, 1922, 1925, 1941, 1958, 2019, 2661, 2818 and RG 2819-R	Anjani and Reddy, 2002 and Anjani *et al.*, 2004
		Kitaiskii, Sangvineus, Gibridnyi sangvineus and Indiiskii-HR	Podkuichenko, 1977
Grey mold	*Botrytis ricini*	TMVCH-MR	http://www.krishisewa.com/articles/castor.html
		RG-2694, 2718, 2724,2731, 2732, 2733-R	Anjani *et al.*, 2004
		Genotypes 65, 83 and 57-T; Genotypes 69 and 58-HS	Batista *et al.*, 1998
		CMR-1-R	Stafford, 1973
		48-1, Jwala-R	http://www.ikisan.com/links/ap_castorDisease% 20Management.shtml
Damping off	*Rhizoctonia solani* AG HG-II	BRS Nordestina variety and Sara hybrid-HS	Basseto *et al.*, 2008
Rust	*Melampsora ricini*	TVC-31-MR	http://www.cabdirect.org/abstracts/20013030017.html
Alternaria leaf spot	*Alternaria ricini*	TVC-31-MR	http://www.cabdirect.org/abstracts/20013030017.html
		T55001 Castor Composite-R	Brigham, 1973
Bacterial wilt	*Ralstonia solanacearum*	DCH-32, 177, 9, 48-1, Local-S	Bora and Das, 2002
Bacterial leaf spot and blight	*Xanthomonas campestris* pv. *ricini*	Culture 6029-R, 9 cultures-MR	Chauhan and Swarup, 1984 Krishun *et al.*, 1980
Bacterial leaf spot	*Xanthomonas ricini cola*	T55001 Castor Composite-R	Brigham, 1973

T = Tolerant; R = Resistant; MR = Moderately resistant; S = Susceptible; HS = Highly susceptible

Table 3 Sources of resistance to insect pests and nematodes in castor

Insect Pest	Causal organism	Sources	Reference
Serpentine leaf miner	*Liriomyza trifoli*	RG1930-R	Anjani, 2003a
		RG 1930 *and RG 2008*-R	*Anjani et al.*, 2008
		RG1771-R	Kapadia, 1995
		Cv. SKI-73 and SKI-89-R	Ramanathan, 2004
		cv. SH-41 and SKI-82-S	Hegde *et al.*, 2009
		RG-52, 149, JI-35-R	
		TVC-15, SHB-392, 48-1, Hiriyur Local, SKI-102, SHB-150, SHB-370 and RHC-25 at Hiriyur, SHB-392, 48-1, Aruna *and Bangalore Local-R*	
Capsule borer	*Conogathes Punctiferalis (Dichocrosis punctiferalis)*	48-1, SHB-556, Hiriyur Local, JI- 130, SKI-129, SKI-126 at Hiriyur and SHB-556, SHB-392, JHB-705, JI-130, 48-1 and SKI- 126	Hegde *et al.*, 2009 Lall *et al.*, 1980
		EB 16-A-less susceptible	http://www.cabdirect.org/abstracts/2001303001 7.html
		Local-HS	Sharma *et al.*, 1995
		TVC-31-R	Patel *et al.*, 1987
		PCS-3, SPS-43-3, VP-1, Aruna-T	
		SHB18, GAUCH1, VHB150 and JI35-S; **Aruna-Less** susceptible	
Semilooper	***Achoea janata L***	TMVCH-MS	http://www.krishisewa.com/articles/castor.html
		TVC-31-R	http://www.cabdirect.org/abstracts/2001303001 7.html
		cry1AB Jyothi and VP1 transformed	
		Cryproteins 1Aa, 1Ab, 1E, 2B, 2A	Malathi *et al.*, 2006
		crylA (b)-R	*http://www.abfindia.org/ge5.html*
		Bt-DOR-4	http://www.abfindia.org/ge5.html
		SHB-392, SHB-150, MCV-10, 48-1, RHC-25, Hiriyur Local at Hiriyur and Bangalore Local, Aruna, SHB-556, SHB-392, SHB-370, RHC-8 and 48-1-R	Madhusudhan *et al.*,2008 Hegde *et al.*, 2009
Bihar hairy caterpillar	*Spilosoma obliqua*	Cry1Aa, 1E, 1Ab	http://www.abfindia.org/ge5.html
Coffee hairy caterpillar	*Euproctis fraterna*	Cry1Ac, 1Aa	http://www.abfindia.org/ge5.html
Tobacco caterpillar	*Spodoptera litura*	1Aa, 2A, 1E, 1F, 1C, 9A-effective	http://www.abfindia.org/ge5.html
		GCH-4 and GCH-5-R	Thanki *et al.*, 2001
		VP-1, CO-1, and JI-35-MR	
		VI-9 and GAUCH-1-HS	
Jassids	*Empoasca flavescens*	VH-60-2/1, VH-64, VH-70/1/4 A, 80852, SKI-3, J1-94-R	Ramanathan, 2004
		RG-48,76,78, 97, 282, 316, 443-R	Jayaraj, 1966
		JI-35, RG 149, 156, 235, 492,500, 504 and 508-R	Dookia *et al.*, 1981
		Udaipur Local-HS	
		R.C. 1098 Baker-R	
		C3 Pakistan-T	
		Dominaca-S	
		TVC-31-R	
	Trialeurodes spp.	TMV5-MR	*Natarajan et al.*, 1986
Whiteflies	*Trialeurodes ricini*	CO-1, EC-103745-R	Ramanathan, 2004
		SA-2, D-3, JGG, JRR, JI-53, JI-1379, 215768, 5912A, EC-80852, EC-97709M-T	SDAU, 2009
		CO-2, E103745, SA-2, D-3, JGG, JRR, Ji-53, 1379, 215768, 5912-A, EC-80852 and EC-97708-T or R	
Reniform nematode	*Rotylenchulus reniformis*	CK-2K-0009, 052, and 005-R	Ramakrishnan *et al.*, 2003
		CK-2K-0001, 0007, 54, 62, *003, 006, 053-056, 059, 060*, 0054, and 0056-MR	
Root-knot nematode	*Meloidogyne javanica and M. incognita*	Lynn, Baker 296, and Baker Hybrid 55-S	Orr and Morey, 1974

T: Tolerant; R: Resistant; MR: Moderately resistant; S: Susceptible; HS: Highly susceptible

Table 4 Sources of multiple resistance to insects, nematodes and fungal diseases in castor

Pest complex	Sources	Reference
Fusarium wilt and root rot	RG 2731, RG 2732 and RG 2733-R	Anjani *et al* 2004
	RG2819-R	*Anjani, 2006*
	JM-6, HC-6, SPS-43-3, Baker-147, 2-73-11, VH-752/6-R	Ramanathan, 2004
Fusarium wilt, root rot and reniform nematode	M619-R	Ramachandram *et al.*, **2003**
Fusarium wilt and reniform nematode	SKP-84-R	Pathak *et al.*, 2006
	SKP-215-R	
Fusarium wilt; root rot; grey rot and reniform nematode	RG-2787-R	Anjani and Raoof, 2009
	VP-1; JI-35; Gauch-1-S to wilt	
	GCH-4; JL-259-S to root rot	
Wilt-nematode complex	GCH-7-R	Ramanadhan 2004
Fusarium wilt and leaf miner	RG 1930 and RG 2008-R	Anjani, 2005
	Sowbhagya-3-S	
Jassids and wilt	GC-2-T	SDAU, 2009
Whitefly and jassid	RG-452, 515, 716-R	SDAU, 2009
Tobacco caterpillar and castor semilooper	cry1EC gene in transformed DCS-9	Sujatha *et al.*, 2009
Root rot	CNPA M. 90-210 and CNPA M. SM4-R	Macêdo Vieira *et al.*,**1998**
Wilt and jassids	CK 940013-R	DOR, 1995
Wilt, root-rot, reniform nematode and nematode -wilt complex	Inbred lines:SKI-80, 90, 147, 160, 215, 217, 218,225, 237, 202 269 232, 266, 267, 271,280,283,285,291, 294, 306,314; and JI-122, 102, 106, 220, 227, 244,256, 258, 263, 273, 303, 314, 319 and 320-R	SDAU, 2009
	Hybrids: SHB 706, SHB 725 , SHB 754, SHB 758,SHB 765, SHB 795, and JHB 665, JHB 882, JHB 887, JHB 888, JHB 905 and JHB 921- R	
Wilt and nematode complex	SHB-725, SHB-754, SHB-758, SHB-759, SHB-760, SHB-764, SHB-765, SHB-793, SHB-795, JHB-865, JHB-880, JHB-882, JHB-887, JHB-888, JHB-905, JHB-906, JHB-921-R	**Sangwan *et al.*, 2005**
	Geetha, SKP-16, SKP-23, 106, 108, SKI 80, SKI 218, SKI 225, and DCS 9-R	

R = Resistant; T = Tolerant; S = Susceptible

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Evaluation of pistillate lines of castor in different seasons

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Abstract

Seven pistillate lines were used to study the stability of pistillate lines over seasons as well as the combining ability. The evaluation was done in the rainy and winter/summer seasons for three years. The pistillate lines VP-1(NR), NES-19 and LRES-17 were stable over the seasons and years while NES-6 and NES-17 were not stable and showed reversion. These lines are therefore, required to be improved for femaleness and stability through selection.

Keywords: Pistillate, monoecious, interspersed staminate flower, reversion environmentally sensitive staminate flower

Introduction

Castor (*Ricinus communis* L.) is one of the important non edible oil seed crops of India. Castor plays an important role in the national economy by earning foreign exchange through export of castor oil. Exploitation of heterosis has been successful in castor and several high yielding hybrids like GAUCH-1, GCH-2, GCH-3, GCH-4, etc., have been released for cultivation (AICRP on castor 2006). Castor provides a unique opportunity for the breeders to use its monoecious nature in the hybrid breeding programme. Commercial exploitation of heterosis is successful due to the availability of pistillate lines (Gopani *et al.*, 1968 and Ramachandram and Ranga Rao, 1988). However, the stability of pistillate lines over seasons plays an important role in the exploitation of pistillate lines. In the present study, pistillate lines *viz.*, VP-1 (NR), VP-1(ER), VP-(LR), NES-6, NES-17, NES-19 and LRES-17 were studied over two seasons for three years to assess the usefulness in hybrid breeding programme of castor.

Materials and methods

The material for the investigation consisted of seven pistillate line *viz.*, VP-1(NR), VP-1(ER), VP-1(LR), NES-6, NES-17, NES-19 and LRES-17, which were grown in three replications by following standard package of practices. Field experiments were conducted continuously in two rainy seasons and three winter seasons. The rainy season experiments were sown during the first week of August in both the years. The winter and summer sowing was done in the last week of November in all the three years. Each entry was sown in three rows with 10 plants/row and all the 90 plants from three replications were observed for sex behaviour at Regional Agricultural Research Station, Raichur campus, UAS, Dharwad. All the recommended cultural practices were followed. Observations were recorded on number of 100% pistillate plants, monoecious plants in each line, early revertants (reversion in secondary, tertiary and quaternary raceme), late revertants (reversion after quaternary raceme) and plants with interspersed staminate flowers (ISF) by following the standard procedures.

Results and discussion

Heterosis breeding played a significant role in increasing the productivity of castor. However, low yields of hybrid seed and lower genetic purity in seed production programmes are the major problems encountered in castor hybrid development. Hence, efforts are being made (i) to increase pistillate nature in female lines and (ii) to reduce sex reversion in female population, for an efficient hybrid development programme, as CMS lines are not available in castor for hybrid development.

Among the seven pistillate lines studied for their pistillate expression during rainy season over two years, it was found that three pistillate lines *viz.*, VP-1 (NR), NES-19 and LRES-17 did not revert to monoecious nature (Table 1). They maintained the pistillate nature up to 8^{th} order of spike. Such stable lines are suitable for hybrid development programme. Such a stability of femaleness tendency during rainy seasons has been reported earlier (Patel *et al.*, 1986; Patel *et al.*, 1990 and Ramachandram and Ranga Rao, 1990). The development of ISF was reported earlier in pistillate lines (Shifriss, 1956 and Zimmerman, 1958).

Among the remaining pistillate lines VP-1 (ER) and NES-17 showed early reversions with a mean of 43.3 and 9.7%, respectively, while VP-1 (ER) and NES-6 showed late reversion with a mean 29.5 and 23.7 (Table 1). They may be improved through cyclic selections and non revertant versions could be developed from them as reported by George and Shifriss (1967) and Anonymous (1990). The early revertant pistillate line VP-1 (ER) has bred true to its early reversion and the number of monoecious plants are the highest (Table 1). The late revertant VP-1 (LR) produced on an average 20% late revertants but the reversion was confined to the spike orders beyond quaternary. Except in VP-1 (ER) and NES-6, the production of interspersed staminate flowers was high varying from 23.0 to 56.7. Thus, the maintenance of all the seven pistillate lines will be hindered wither due to the production of early late revertants or ISF in the rainy season.

During the rainy season maximum temperature varied from 29 to 36°C and 28.5 to 36.0°C while minimum temperature ranged from 13.1 to 24.5°C and 13.1 to 24.0°C in both the years. The three lines VP-1 (NR), NES-19 and LRES-17 expressed 100% pistillate nature in rainy season i.e. pistillateness (Table 1) up to 8th order. Later the same genotypes in summer expressed interspersed staminate flowers (ISF) from 20 to 65% (Table 2). Zimmerman and Smith (1966) had also suggested using interspersed staminate flowers as pollen source for the maintenance of pistillate lines. Higher atmospheric temperature (> 33°C) *promoted interspersed flowers, while lower temperature* (< 33°C) *resulted in fully female raceme* (Patel, 1989) in three lines and they are highly suitable for hybrid seed production.

Table 1 Stability of pistillate lines over two rainy seasons in castor

Pistillate	Season	Percentage of plants with				
		Stable pistillateness	Monoecious	Early revertants	Late revertants	ISF
VP-1(NR)	R_1	100.00	0.00	0.00	0.00	36.67
	R_2	100.00	0.00	0.00	0.00	33.33
	Mean	100.00	0.00	0.00	0.00	35.00
VP-1(ER)	R_1	73.33	26.67	31.82	27.27	0.00
	R_2	73.33	26.67	54.55	18.18	0.00
	Mean	73.33	26.67	43.20	22.73	0.00
VP-1(LR)	R_1	90.00	10.00	0.00	33.33	20.00
	R_2	90.00	10.00	0.00	25.93	25.93
	Mean	90.00	10.00	0.00	29.63	22.96
NES-6	R_1	89.53	10.47	0.00	19.48	0.00
	R_2	89.41	10.59	0.00	23.68	0.00
	Mean	89.47	10.53	0.00	23.68	0.00
NES-17	R_1	75.29	24.71	9.38	42.18	48.44
	R_2	71.43	28.57	10.00	25.00	65.00
	Mean	73.36	26.64	9.69	33.56	56.72
NES-19	R_1	100.00	0.00	0.00	0.00	43.33
	R_2	100.00	0.00	0.00	0.00	36.67
	Mean	100.00	0.00	0.00	0.00	40.00
LRES-17	R_1	100.00	0.00	0.00	0.00	36.67
	R_2	100.00	0.00	0.00	0.00	30.00
	Mean	100.00	0.00	0.00	0.00	33.35

R_1 = Rainy season of 1993 and R_2 = Rainy season of 1994

The evaluation of pistillate lines in post rainy season over three years (Table 2) indicated 100% non revertant plants with ISF nature in VP-1(NR), NES-19 and LRES-17, while, early revertants were high in VP-1 (ER) followed by NES-6 and NES-17. The maximum atmospheric temperature of post rainy in all the three years was around 42-43°C. Similar results *were reported by* Patel *et al.* (1986). *The percent of plants with ISF varied from 10% in VP-1(ER), in R1 season to 75% in* VP-1(LR) in R^2 season (Table 2).

From the data (Table 1 and 2) it was also evident that there was high reversion (male induction) in female plant population under high temperature (>32°C) as compared to low temperature (<32°C). Hence, the hybrid seed production under low temperature (<32°C at flowering time during rainy season) and maintenance of female lines under high temperature (summer) is advantageous for the recovery of high seed yield with high genetic purity. Patel *et al.* (1986) and Ramachandram and Ranga Rao (1990) have also reported similarly, about maintenance of pistillate lines at higher temperature and hybrid seed production during winter season.

Studies on sex expression of seven pistillate lines, confirmed that three lines *viz.*, VP-1 (NR), NES-19 and LRES-17 had interspersed nature of flowering during summer season and expressed stable pistillate behaviour, during the rainy season. It is advocated to use 'N' or 'S' type lines with environmentally sensitive interspersed staminate flowers (ESISF), for the maintenance of pistillate lines and to produce hybrid seeds with high genetic purity.

Table 2 Behaviour of interspersed nature of pistillate lines over three post-rainy seasons in castor

Pistillate	Seasons	Percentage of plants with			
		Pistillateness	Early revertant	Late revertant	ISF
VP-1(NR)	R_1	90.00	0.0	0.00	100.00
	R_2	100.00	0.00	0.00	100.00
	R_3	100.00	0.00	0.00	100.00
	Mean	96.67	0.00	0.00	100.00
VP-1(ER)	R_1	100.00	56.67	33.33.	10.00
	R_2	83 33	60.00	20.00	20.00
	R_3	83.33	48.00	24.00	28.00
	Mean	88.00	54.69	25.78	19.33
VP-1(LR)	R_1	90.00	0.00	44.44	55.56
	R_2	93.33	0.00	25.00	75.00
	R_3	93.33	0.00	35.71	64.29
	Mean	92.22	0.00	35 05	64.95
NES-6	R_1	96.55	39 26	28 58	32.14
	R_2	96.67	24 14	34.48	41.38
	R_3	90.00	18.52	22.22	59.26
	Mean	94.41	27 31	28.43	44.26
NES-17	R_1	73.33	36.36	31.82	31.82
	R_2	80.00	16.67	50.00	33.33
	R_3	73.33	36.36	31 82	31.82
	Mean	77.78	23.23	41.46	35.61
NES-19	R_1	86.67	0.00	0.00	100.00
	R_2	93.33	0.00	0.00	100.00
	R_3	100.00	0.00	0.00	100.00
	Mean	93.33	0.00	0.00	100.00
LRES-17	R_1	100.00	0.00	0.00	100.00
	R_2	100.00	0.00	0.00	100.00
	R_3	100.00	0.00	0.00	100.00
	Mean	100.00	0.00	0.00	100.00

R_1= post rainy season1992-93; R_2= post rainy season 1993-94 and R_3= post rainy season1994- 95

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Trait specific analysis of castor (*Ricinus communis* L.) germplasm for delineation of areas of diversity in Andhra Pradesh using DIVA-GIS

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Abstract

Castor germplasm was collected by NBPGR Regional station, Hyderabad from Andhra Pradesh during crop specific as well as other collection missions over the years (1988-till date) for conservation and utilization of genetic diversity. *In-situ* traits were recorded on 122 accessions while collecting the germplasm. The traits stem colour, stem type, leaf type, bloom, node number, nature and size of the capsule, which are significant phenotypic characters in identification of promising lines for dwarf types (node number) and resistant sources for important diseases, wilt (stem type), grey rot (nature and size of the capsule) and sucking pests (bloom and leaf type) were subjected to DIVA-GIS analysis. Based on the GIS analysis parts of Warangal and Khammam districts, which were harbouring diverse lines were identified as areas of diversity for the traits studied. These rich pockets should be targeted for collection of trait specific germplasm, for sources against biotic stresses and also for taking up in-situ on-farm conservation of castor diversity.

Keywords: Diversity, germplasm, DIVA-GIS, *Ricinus communis*

Introduction

Castor is believed to have originated in Tropical Africa and India is considered as a secondary centre of diversity. The centre of origin in Tropical Africa and Indo-Gangetic plains in India are the world centres of variability for castor (Kulkarni and Ramamurthy, 1977; Duhoon *et al.*, 1996 and Anjani *et al.*, 1999). The species grows throughout the country in all climates ranging from tropical, sub-tropical to temperate with high concentration of diversity occurring in the drier parts of tropical climate. Castor oil is one of the most useful and economically important plant oil with varied uses. India with 59.1% of the area, 64.0% of the total production and with a productivity of 1,146 kg/ ha is the world leader in castor seed production and meets 90% of the world's castor oil requirement (Pathak, 2009). In India, Andhra Pradesh is the second major castor growing state after Gujarat.

Diverse germplasm that harbour good traits with respect to production potential and tolerance/ resistance to biotic and abiotic stresses is essential in castor breeding programmes for its improvement. The National Gene Bank (NGB) at NBPGR, New Delhi is conserving over 2,600 accessions collected from diverse agro-ecological regions of the country. The national priorities for exploration and collection of germplasm are for sources of resistant to *Botrytis* grey rot and *Fusarium* wilt, the two major biotic challenges in castor cultivation (Padmaraju and Ashok Kumar, 2002). NBPGR Regional station, Hyderabad during crop specific as well other collection missions has made earnest efforts to collect and conserve castor germplasm from Andhra Pradesh (Pandravada *et al.*, 2000) . Special focus was made on collection of trait specific germplasm in targeted regions to facilitate identification of diversity rich pockets. With the above objective, an attempt has been made to subject 122 accessions of the total germplasm augmented to DIVA-GIS analysis to identify the regions of diversity for specific traits in this paper.

Materials and methods

Castor germplasm collected from various agro-ecological zones of Andhra Pradesh had been populated. The castor germplasm of 122 accessions were collected during a specific survey undertaken in Warangal, Khammam, West Godavari and Guntur districts of Andhra Pradesh. The region is agro-ecologically varied and has a tradition of growing castor as a shade crop in turmeric and ginger fields. The surveyed region in the districts of Warangal and Khammam which form part of northern Telangana zone, receive an annual average rainfall of 900-1150 mm from the south west monsoon with maximum and minimum temperatures ranging from 32°C - 37°C and 21°C- 25°C, respectively and predominated with red soils. The other surveyed region in the districts of West Godavari and Guntur fall under Krishna-Godavari zone receive an average rainfall of 800-1100 mm with maximum and minimum temperatures ranging from 32°C-36°C and 23°C-24°C, respectively and predominated with alluvial, red and black soils. The passport information comprising of village, mandal and district along with latitude, longitude and altitude were recorded for all the collected germplasm. The altitude of the area surveyed ranged from 30-460 msl. Mature capsules/ heads/ seeds were collected using random (Hawkers, 1976) and biased (Harlan, 1975) sampling methods to augment specific genotypes (Sinha, 1981). *In-situ* data pertaining to traits stem colour, plant height, node number, nature of the stem, branching type, leaf size and shape, presence or absence of the bloom, nature of the raceme, spike size and shape, nature of the capsule (spiny and non spiny) and capsule size were also recorded.

Keeping in view the needed research thrust for identification of resistant sources in early and dwarf types against wilt, grey rot disease and sucking pests viz. jassids, white flies and thrips, important phenotypic qualitative traits *viz*, stem colour, stem type, node number, leaf type, bloom, nature of the capsule and capsule size were also recorded as data input to identify the geographical regions of diversity using the DIVA-GIS software version 7.1.6.

Results and discussion

In the collection missions undertaken by NBPGR Regional Station, Hyderabad, a total of 245 accessions of castor germplasm were collected from 15 districts in Andhra Pradesh. The important districts in which native diversity in castor occurs include Karimnagar, Khammam, Nalgonda, Nellore, Mahaboobnagar, Prakasam, Rangareddy and Visakhapatnam districts in Andhra Pradesh and Khammam, Ranga Reddy, Mahaboobnagar and Visakhapatnam specifically for perennial castor germplasm diversity. The landraces collected included *Amudamu, Chettu amudam, Chitti amudam, Kondangi amudalu, Konda amudam, Neronda amudam, Pedda amudam, Vonta amudam*. Significant diversity was observed in plant habit, plant height, branching, stem colour, inflorescence compactness, % of staminate flowers, capsule nature (smooth/ spiny), days to maturity, seed size, testa colour/ pattern and oil percentage etc. The diversity in perennial castor is very interesting, the age of which ranged from 1-6 years with large big size of the inflorescence, capsules and seeds. In perennial castor, the seed size of which is twice that of the cultivated annual castor might be useful in breeding castor for increasing the seed size, weight and oil content (4% more than Aruna). The perennial castor (*Chettu amudamu*) the seed size of which is very big is used for extraction of edible oil in Khammam and Visakhapatnam districts. Perhaps these genotypes might be having less or no bitter principle/ rancidity and deserves further research.

In the crop specific survey undertaken in four districts, a total of 122 accessions comprising of 63 landraces and 59 primitive cultivars could be collected. The castor collections exhibited variation in stem colour, presence/ absence of bloom, node number, plant height, nature of raceme, size, shape and compactness of spike, nature, size and dehiscence of capsule (Sunil *et al.*, 2005).

The diversity analysis carried out on these 122 accessions using DIVA-GIS revealed high Shannon diversity index (0.78 to 1.0) for stem colour, which basically had three different colours *viz.*, red, green and purple in the germplasm collected from southern parts of Khammam and East Godavari districts (Fig.1). While the red stem in castor is due to the presence of anthocyanin pigment, the green stem is highly heritable and is used as a distinguishable morphological trait in varietal identification (Anonymous, 2004). High diversity index (0.63 to 1.0) for stem type, which had two types (woody and non-woody), was recorded from almost all the regions surveyed (Fig. 2). There is significant correlation with the tall and woody types grown as a border crop on bunds being free from wilt. In leaf type, which basically comprised of flat and shallow cup, the germplasm with high diversity based on diversity index value (0.36 to 1.0) could be sourced from Guntur district (Fig. 3). For collecting highly diverse lines for bloom (wax coating on the stem and leaves) ranging from zero bloom, single bloom, double bloom and triple bloom, pockets in Warangal and Khammam district should be targeted (Fig. 4) and similar is the case for collecting accessions with diverse node numbers with three states with low node, high node and very high node (Fig. 5). The presence of bloom is an important character in imparting resistance to sucking pests in castor. While the jassid infestation is less in accessions with triple bloom nature, the white fly and thrips infestation is less in accessions with zero bloom. The germplasm accessions with low node number were of dwarf types with early maturing nature. Early maturity is highly desirable in castor to fit in the genotypes in various cropping systems. In the present era of low rainfall, unequal distribution and early cessation, early maturing genotypes will be able to give some assured yield to the castor farmers. In addition, early maturing genotypes escapes the heavy incidence of *Botrytis* grey rot which generally appears late in the season. For germplasm with spiny and non-spiny capsules, Warangal and Guntur are diversity rich pockets (Fig. 6), for capsule size, which was categorized as small, medium and large, Warangal is the ideal district for diversity richness (Fig. 7).

Thus, the diversity analysis using software DIVA-GIS may result in identification rich pockets for collection of trait specific germplasm, for sources against biotic stresses and also for taking up in-situ on-farm conservation of castor diversity for sustainable utilization of genetic diversity in its improvement. Similar analysis on more than 2,600 accessions of castor germplasm conserved in the NGB which were collected from diverse agro-ecological zones of the country would result in identification and delineation of more useful pockets of diversity.

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Fig.1. DIVA-GIS diversity analysis for stem colour

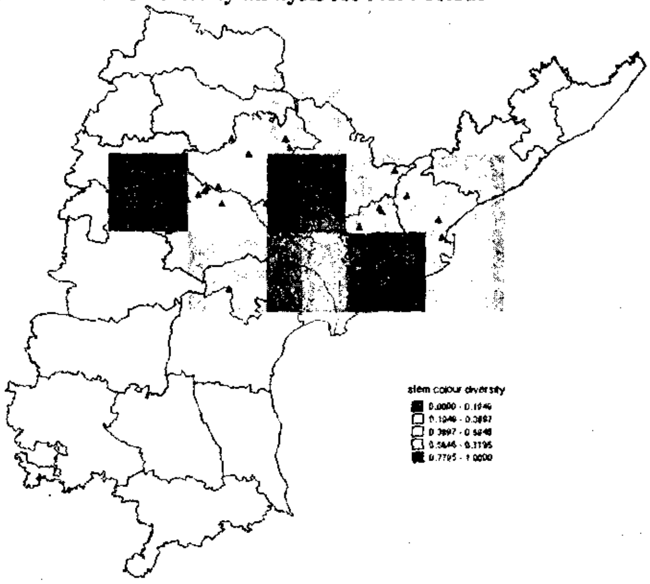


Fig.2. DIVA-GIS diversity analysis for stem type

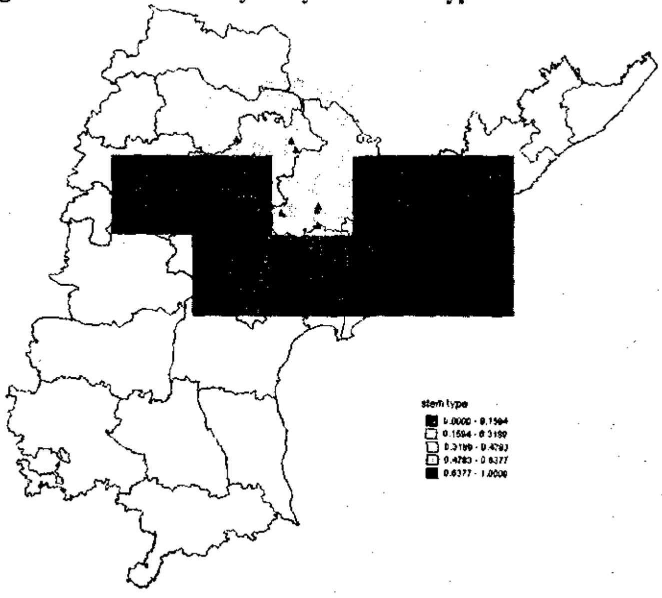


Fig.3. DIVA-GIS diversity analysis for leaf type

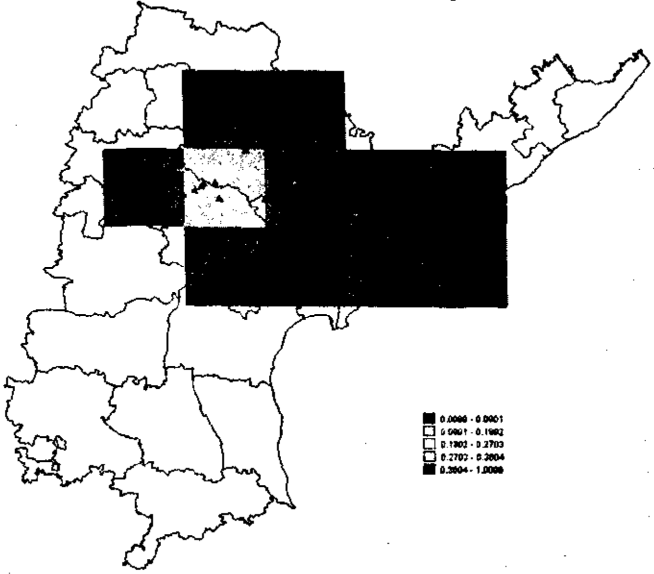


Fig.4. DIVA-GIS diversity analysis for bloom

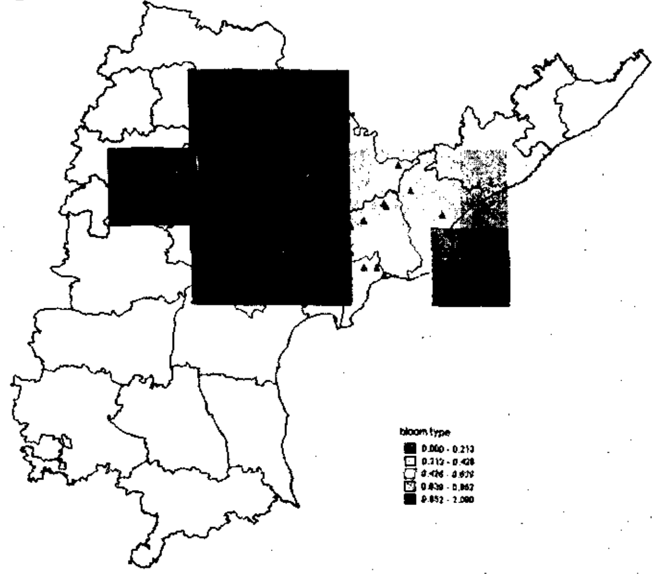


Fig.5. DIVA-GIS diversity analysis for node number

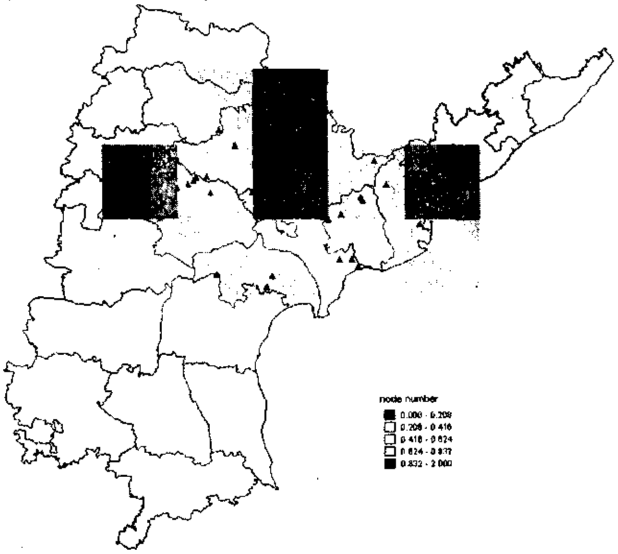


Fig.6. DIVA-GIS diversity analysis for capsule nature

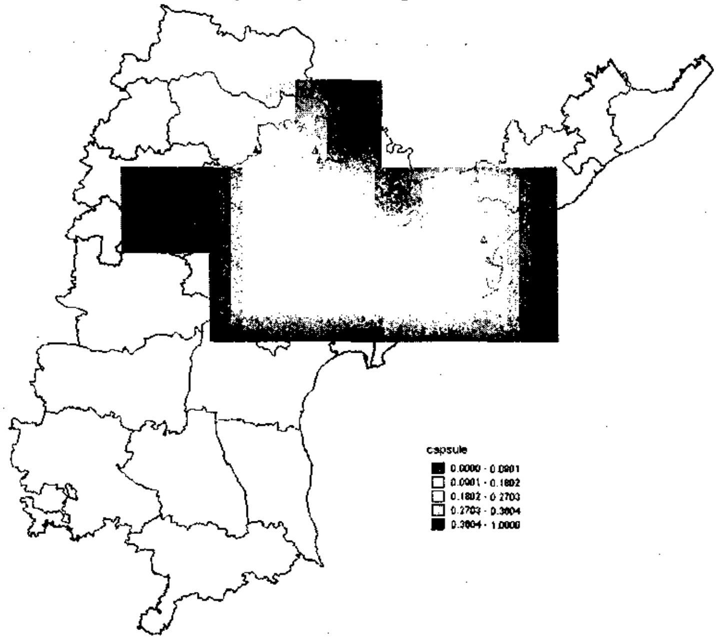
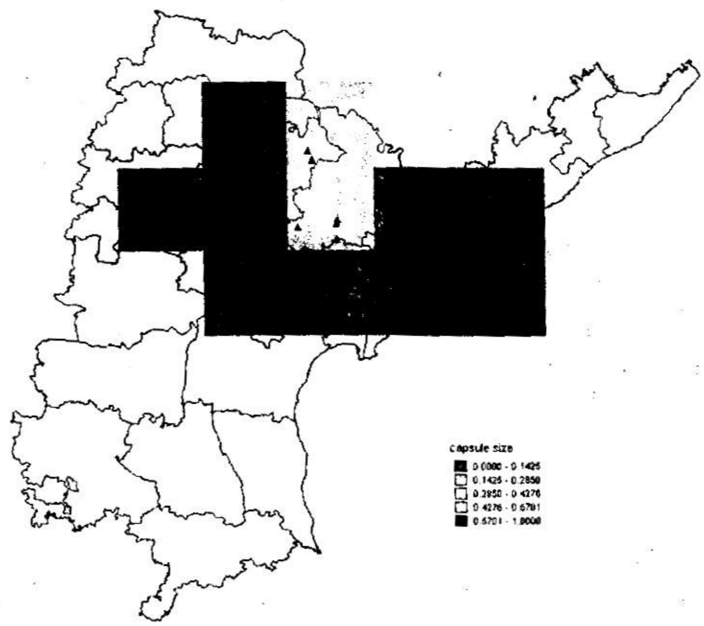


Fig.7. DIVA-GIS diversity analysis for capsule size



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Studies on combining ability for maturity and maturity related traits over two seasons in castor, *Ricinus communis* L.

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Abstract

In the present study, five pistillate lines and 14 tester lines were crossed in a linextester design to generate 70 hybrids and evaluated along with 19 parents as a separate block in a randomised block design to identify superior general combiners for maturity and yield traits. Analysis of variance for combining ability revealed that both additive and non-additive genetic variances were important in the inheritance of various maturity traits. But, a preponderance of additive gene action for maturity related traits was evident based on observation of significantly higher ratio of *gca:sca* variance. With respect to the general combining ability effects, VP-1 among lines and Aruna, RG358 among testers were found to be good general combiners for plant height. For maturity traits line NES2 and tester Aruna, RG360 recorded significantly highest *gca* effects. So these promising genotypes could be efficiently used in the development of castor cultivars for earliness and plant height manipulations. Further, with respect to specific combining ability, the crosses LRES-17 x RG-135, NES6 x 48-1 recorded significantly highest *sca* effects followed by nine other crosses. These crosses finds significance for heterosis breeding for earliness. Among all these crosses, the cross NES17 x RG360 was a good specific combiner for early maturity along with higher *per se* for seed yield/plant and can be effectively used in heterosis breeding program in castor. Significantly positive correlation was observed between *gca* and *per se* performance of parents for most of the maturity traits and yield performance (seed yield and oil yield/plant) for two seasons. So, selections could be efficiently practiced on parents and also segregating derivatives based on mean performance to derive early maturing castor cultivars having high seed yield and oil yield.

Keywords: Castor, genetic variance, maturity traits

Introduction

India is the first country in the world to exploit hybrid vigour in castor crop. Development of hybrid involves improvement of pistillate base and development of monoecious combiners. A number of new diverse pistillate lines and monoecious lines were developed either through conventional or mutation breeding. An attempt has been made to study the combining ability of new pistillate and monoecious lines for maturity, maturity related trails and other characters.

The combining ability indicates the ability of a genotype to transmit superior performance to its crosses. The value of an inbred line depends on its ability to produce, superior hybrids in combination with other inbreds. Combining ability estimation i.e., general and specific combining ability effects assure importance in the choice of selection procedure to obtain superior recombination in the segregating population or to exploit heterosis. Combining ability often depends upon complex interaction system among genes.

The combining ability estimates are free from genetic assumptions and are based on empirical results. The estimates of *gca* and *sca* effects are based on first order statistics (mean values) and hence are statistically robust.

Materials and methods

The experimental material consisted of five pistillates lines *viz.*, VP-1 (NR), NES-6, NES-17, NES-19 and LRES-17 and fourteen (14) testers *viz.*, VP-1 (M), 48-1, Aruna, RG-202, RG-217, RG-359, RG-358, RG-360, RG-363, RG-374, RG-135, SH-63, Bhagya and SH-41. These parents were used to produce to hybrids in a Line x Tester (L x T) mating design. All the 70 crosses along with 19 parents were grown in a separate parental block in a randomized block design with three replications at the RARS Raichur, UAS, Dharwad. Each entry was grown in three rows. The distance between rows was 90 cm, while between the plants 45 cm. All the recommended cultural practices were followed. Observations were recorded on five randomly selected plants in each entry in every replication for nine maturity related characters over two seasons. Combining ability analysis was done according to Kempthrone (1957).

Result and discussion

Analysis of variance for combining ability revealed that both additive and non-additive genetic variance were important in the inheritance of various traits as evident from significance of females, females v/s males and males in both the seasons except for plant height (S_1 QS_2 among internodal distance (in S^2) and Bartlett's rate of index for both the seasons. The analysis indicated significant variation among males and females for these characters which is essential for the proper elucidation of gene action. These results are in agreement with the earlier reports (Giriraj *et al.*, 1973; Joshi, 1993; Solanki, 2001 and Mahanthashivayogayya and Kenchanagoudar, 2002).

The relative magnitude of variance due to *gca* (additive) and *sca* (non-additive) is very useful as a guiding factor to decide the breeding strategies to be employed on the material studied. When the portion of additive variance is more, it is possible to get full response when simple selection is practiced. Among the maturity related characters, the ratio of *gca* vs. *sca* was nearly double or more for days to flower initiation on primary raceme, days to 50% flowering on primary raceme, days to 100% flowering on primary raceme, days to 100% maturity on primary raceme in both the seasons and for plant height in S_1 indicating the predominance of additive variances in the inheritance of these characters. Some of the earlier workers have also reported the importance of additive variance for these characters (Patel *et al.*, 1984; Patel, 1985 and Pathak, *et al.*, 1989).

Table 1 General combining ability effects of lines and testers for maturity and maturity related traits over two seasons in castor

Parents	Plant height (cm)		Days to flowering initiation on primary raceme		Days to 50% flowering on primary raceme		Days to 100% flowering on primary raceme		Days to 100% maturity on primary raceme	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Lines										
VP-1 (NR)	14.01**	11.8**	5.31**	4.44**	5.12**	4.04**	4.80**	3.44**	3.10**	2.44**
NES-6	-15.14**	-12.48**	-6.47**	-6.47**	-6.14**	-5.86**	-5.49**	-5.18**	-4.98**	-4.96**
NES-17	-3.66**	1.1*	1.35**	-0.80**	-1.38**	-0.81**	-1.39**	-0.54	-0.60*	-0.37
NES-19	-0.24	-0.73	0.27	0.37	0.34	0.11	0.35	-0.04	0.36	0.16
LRES-17	-5.04**	0.31	2.24**	2.46**	2.05**	2.52**	1.73**	2.32**	2.12**	2.73**
SE (gi)	0.21	0.533	0.215	0.278	0.223	0.306	0.228	0.334	0.268	0.301
CD@5%	0.412	1.045	0.421	0.545	0.437	0.600	0.447	0.655	0.525	0.590
CD@1%	0.541	1.373	0.554	0.716	0.574	0.788	0.587	0.860	0.690	0.775
SE (gi-gj)	0.297	0.754	0.304	0.393	0.315	0.432	0.322	0.472	0.380	0.425
CD@5%	0.582	1.478	0.596	0.770	0.617	0.847	0.631	0.925	0.745	0.833
CD@1%	0.765	1.942	0.783	1.012	0.811	1.113	0.829	1.216	0.979	1.095
Testers										
VP-1 (M)	1.11**	-4.50**	3.95**	1.61**	3.81**	1.84**	3.89**	2.41**	1.91**	0.64
48-1	1.75**	-2.31**	-0.52	-1.79**	-0.32	-1.29*	-0.44	-0.86	0.18	-0.82
Aruna	2.39**	-4.96**	-5.05**	-6.05	-5.45**	-6.02**	-4.64**	-5.19**	-3.56**	-4.09**
RG-202	-0.89*	0.29	-0.79*	0.08	-0.72	-0.02	-1.11**	0.34	0.91*	0.58
RG-217	-3.63**	1.80*	-2.39**	-0.45	-1.65**	0.91	-0.58	0.88	-0.22	0.64
RG-359	0.14	4.41**	2.888**	3.01**	2.41**	3.11**	2.09**	3.01**	2.58**	2.71**
RG-358	3.62**	5.29**	1.55**	3.01**	1.68**	3.24**	1.49**	2.54**	1.78**	1.98**
RG-360	-1.57**	2.84**	-3.45**	-2.52**	-3.19**	-2.44**	-2.38**	-1.99**	-1.49**	-0.82
RG-363	-3.89**	4.52**	-0.99**	0.55	-0.25	0.44	0.42	0.21	-0.02	-0.56
RG-374	7.14**	12.93**	3.81**	5.21**	4.15**	3.91**	3.22**	3.48**	3.64**	3.44**
RG-135	-12.77**	-10.34**	-2.99**	-3.59**	-3.12**	-3.82**	-3.58**	-4.32**	-3.76**	-3.56**
SH-63	3.87**	0.30	3.28**	1.08*	3.28**	1.51**	3.02**	1.28**	1.64**	2.64**
Bhagya	0.54	-3.90**	0.08	-0.59	-0.85*	-1.62**	-1.64**	-2.26**	-2.82**	-1.96**
SH-41	1.69**	-6.79**	0.61	0.410	0.21	0.31	0.22	-0.12	-0.76	-0.82
SE (gi)	0.352	0.893	0.360	0.465	0.373	0.511	0.381	0.559	0.444	0.503
CD (P=0.05)	0.67	1.750	0.706	0.911	0.731	1.002	0.747	1.096	0.880	0.986
CD (P=0.05)	0.907	2.300	0.927	1.198	0.961	1.306	0.981	1.440	1.157	1.296
SE (gi-gj)	0.497	1.262	0.509	0.658	0.528	0.723	0.539	0.790	0.636	0.712
CD (P=0.05)	0.974	2.474	0.997	1.290	1.034	1.417	1.056	1.548	1.246	1.395
CD (P=0.05)	1.28	3.251	1.311	1.695	1.360	1.862	1.388	2.035	1.638	1.834
σ^2 *gca*	166.55	107.64	30.02	26.91	27.48	22.84	22.28	17.67	14.99	14.85
σ^2 *sca*	73.82	94.13	11.94	11.72	11.70	11.16	11.79	10.04	9.64	7.86
σ^2 *gca/sca*	2.26	1.14	2.61	2.30	2.25	2.05	1.89	1.76	1.55	1.89

The magnitude of these ratios was also consistent over the seasons indicating their consistency. For other characters *viz.*, nodes to the primary raceme (except S^2 season), average internodal distance (except S^2 season), Bartlett's rate of index for yield (except S_1 season) and plant height (except S_1 season), days to absolute maturity (except S_2 season) were all near unity indicating the equal importance of both additive and non additive variance. Similarly many workers reported equal importance of both (Yadav *et al.*, 1978; Singh and Yadav, 1982) for height) and (Bhatt and Reddy, 1983) for days to flowering. However, as discussed earlier, days to flower initiation on primary raceme, days to 50% flowering on primary raceme, days to 100% flowering on primary raceme, days to 100% maturity on primary are the most reliable indication of maturity and it is worth noting that all these traits appeared to be to help in improvement in the present material. Similar results were reported by Patel *et al.* (1984).

When scored over the set of characters related to maturity, NES-6 (-7, -7 in S1 and S2) and NES-17 (-6, -1 in S_1 and S_2) among the lines showed high negative scores in both the seasons, indicating that they are good combiners for earliness. While, among testers RG-135 (-6 and - 6) RG-360 (-7 and -5) Bhagya (-4 and -6), Aruna (-4 and -5) and 48-1 (0 and -5) were general combiners in both the seasons. The desirable combining ability nature of parents for earliness has been brought out by Hooks *et al.* (1971); Patel *et al.* (1984) and Pathak *et al.* (1989). While the parents *viz.*, VP-1 (NR), RG-358, RG-374, did not exhibit *gca* positive effects for the plant height. Chakraborty (1997) reported similar results for the M-591 parent.

The *gca* effects of lines and testers was analysed for different maturity and maturity related traits for two seasons in castor (Table 1). Among the different lines tested, line VP-1 was a good combiner, with significant *gca* effects over two seasons for plant height while NES2 was good general combiner in desirable direction for days to flower initiation on primary raceme, days to 50% flowering on primary raceme, days to 100% flowering on primary raceme and also with respect to days to 100% maturity on primary raceme.

Among the testers, Aruna recorded significant negative gca effects in desirable direction with respect to most of the flowering and maturity traits (Table 1) followed by the tester RG-360. Aruna also displayed significantly high positive *gca* effects for plant height followed by RG-358. So, these promising genotypes *viz.*, NES6, Aruna and RG-360 could be used for breeding for earliness and lines VP-1, RG-358 for plant height manipulations. Similar kind of studies for identification of extra early germplasm lines for breeding extra cultivars in castor was done by Anjani (2010). Further analysis was also done to check the significant relationship between *gca* and *per se* performance of parents for maturity and yield performance for two seasons (Table 2). Results revealed significant positive correlation between *gca* and *per se* values for important yield traits like oil yield/plant, seed yield/plant (g), hundred seed weight (g), number of capsules/plant and also for maturity traits like days to 100% maturity, days to 50% flowering on primary raceme and days to flowering initiation on primary raceme. Hence, selection could be practiced among the parents for good parental combinations based on the *per se* values for above traits would be effective in deriving early maturity genotypes with high seed yield and oil yield. Similar kind of observations for selection of traits based on combining ability studies for seed and yield components in castor was reported by Barad *et al.* (2009).

Having quantified relatively the magnitude of additive and non-additive variation, the crucial step would be to identity specific cross combination for further handling either for heterosis breeding or for isolating pure breeding genotypes to identify varieties. For this purpose the crosses should necessarily be heterotic particularly over the standard check.

Out of 70 crosses, 18 crosses which exhibited high mean values for maturity and maturity related traits in castor respectively were consistent with high scores for maturity related traits in both seasons, for *sca* effects indicating these crosses as good specific combiners for early maturity. Out of 18 crosses these 11 crosses *viz.*, VP-I (NR) x RG-358, VP-I (NR) x Bhagya, NES-6 x 48-1, NES-6 x Aruna, NES-6 x RG-202, NES-6 x RG-217, NES-17 x 48-1, NES-17 x RG-359, NES-17 x RG-360, NES-17 x RG-363 and LRES-17 x RG-135 were promising specific combiners which can be considered for exploitation of heterosis for early maturity (Table 3). The cross NES-17 x RG-360 was a good specific combiner for maturity with high mean performance of seed yield (Table 3) .

Table 2 Inter-relationship between *gca* and *per se* performance of parents for maturity traits and yield parameters in castor over two seasons

Characters	Coefficient of correlations between *gca* and parents *per se*	
	S1	S2
Plant height (cm)	0.361	0.637**
Days to flowering initiation on primary raceme	0.473*	0.491*
Days to 50% flowering on primary raceme	0.470*	0.472*
Days to 100% flowering on primary raceme	0.552*	0.387
Days to 100% maturity on primary raceme	0.649**	0.489*
Capsules on secondary racemes/plant	0.633**	0.346
Effective racemes/plant	0.569*	0.187
Capsules/plant	0.713**	0.590**
Hundred seed weight (g)	0.880**	0.876**
Seed yield/plant (g)	0.820**	0.763**
Oil content (%)	0.394	0.494*
Oil yield/plant (g)	0.815**	0.821**

Table 3 **Specific combining ability effects of promising cross combinations for absolute maturity and seed yield/plant (g) over two seasons in castor**

Cross	Days to absolute maturity		Castor Seed yiel/plant (g)	
	S1	S2	S1	S2
VP-I (NR) x RG-358	-8.23**	-8.16**	-19.65**	10.90**
VP-I (NR) x Bhagya	-10.50**	-8.70**	-8.51**	-17.43**
NES-6 x 48-1	-17.05**	-18.02**	-9.18**	-27.19**
NES-6 x Aruna	-6.51**	-6.36**	0.38	-4.62
NES-6 x RG-202	-5.58**	-7.62**	-8.48	-6.80*
NES-6 x RG-217	-7.38**	-7.16**	-3.94**	-6.94**
NES-17 x 48-1	-8.95**	-6.88**	-9.20**	8.63**
NES-17 x RG-359	-4.42**	-5.95**	8.86**	2.02
NES-17 x RG-360	-7.42**	-5.21**	15.71**	32.42**
NES-17 x RG-363	-5.49**	-7.48**	-7 83**	-9.45**
LRES-17 x RG-135	-23.92**	-21.99**	0.99	6.57*
SE (si)	1.568	1.858	1.319	2.680
CD (P=0.05)	3.073	3.642	2.585	5.253
CD (P=0.05)	4.039	4.786	3.398	6.904
SE (si-sj)	2.218	2.628	1.865	3.790
CD (P=0.05)	4.347	5.151	3.656	7.428
CD (P=0.05)	5.713	6.769	4.804	9.763

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Exploration of cytoplasmic male sterility sources in castor - A concept note

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Abstract

Commercial exploitation of heterosis is based on a two-line breeding system using sex variants in castor. The successful exploitation of a three line breeding system using cytoplasmic male sterility (CMS) in other oil seed crops like sunflower, rapeseed-mustard, safflower gave insights into the concept of exploring the sources of CMS even in castor. The present paper discusses the origin and causes of male sterility in sunflower and possible ways of exploration in castor.

Keywords: Castor, CMS system

Introduction

The two line system of heterosis breeding in castor is based on development of stable pistillate line and a suitable monoecious or inbred line as a male line. Pistillate mechanism in castor is controlled by both genetic and non genetic factors. The genetic mechanism may be dominant and epistatic as in S type, recessive in N type or a combination of both in NES type. The non genetic factors, temperature, relative humidity, age of the plant, nutrition, moisture and growth regulators mainly cause variation in sex tendency and sex pattern. Sex variants in castor vary from monoecious, pistillate, sex revertants and pistillate with interspersed staminate flower (ISF) etc. The highly unstable nature of the parental lines in castor coupled with lack of proper isolation distance, laxity in rouging led to huge losses by rejection of seed lots. The losses are estimated to be ₹ 7089.36 lakhs for 4 hybrids and ₹ 240.72 lakhs for VP-1 pistillate line during 1992-2002 (Zaveri, 2009) period. In this context, a stable source of CMS line in castor need to be explored to avoid the problem of sex variants in castor.

Male sterility, reported for the first time by Kolreuter (1763) in Maize, is defined as the failure of plants to produce functional anthers, pollen, or male gametes. Male sterility may arise due to multiple causes like adverse growth conditions, occurrence of diseases, or due to mutations. Naturally occurring genetically male sterile plants in hermaphrodite species generally maintain fully normal female functions. The phenotypic manifestations of male sterility are very diverse from the complete absence of male organs, the failure to develop normal sporogenous tissues due to absence of meiosis, the abortion of pollen at any step of its development, indehiscence of stamens dehiscence, the inability of mature pollen to germinate on compatible stigma. Although pollen abortion occurs due to multiple causes, cytoplasmic male sterility, which depends on mitochondrial genes, is the determinant of gynodioecy most frequently met in natural populations. The role of sterility-inducing mitochondrial genes in the maintenance of sexual dimorphism in plant species is identified by molecular biologists.

Sources of male sterility in castor for consideration

Spontaneous mutants: Majority of the sources of CMS in crops like sunflower, rapeseed, mustard, pearl millet, sorghum and rice were developed from the spontaneous mutants identified in the germplasm. There are about 3500 germplasm accessions being maintained in germplasm maintenance unit at DOR, Hyderabad which need to be thoroughly screened for the sources of cytoplasm. Initial screening may be based on morphological indicators like shy bearing, absence of seed setting on selfing, continuous flower abscission, etc. Simple tests for anther morphology, presence or absence of pollen grains can be done by rubbing anthers between thumb and first finger which can be further confirmed with pollen studies using 2% aceto carmine and Alexander's solution. Any plant with >90% pollen sterility can be further advanced after confirming the fertility of the female.

Intra specific crosses: Spontaneous male sterile plants may occur when crosses involve diverse parents (P_1 and P_2). Such male sterile plants can be confirmed by anther morphology and pollen sterility studies. In case of monogenic recessive control, male sterile plants occur in F_2 which can be confirmed by back crossing with both the parents. The cytoplasmic source of CMS is confirmed, if all the back cross generation plants with P_2 (male plant) are all male sterile while the F_2 of a reciprocal cross ($P_2 \times P_1$) will have only male-fertile plants.

Wide hybridization: The first stable source of CMS in sunflower was discovered by Leclercq in 1969 from an interspecific cross involving *Helianthus petialaris* Nutt. and *Helianthus annuus* L. Subsequent identification of genes for fertility restoration was discovered by Kinman in 1970 and allowed for efficient and economical production of hybrid seed. Inter-specific and inter-generic hybridization have been the principal source of CMS in several crop plants. Among 287 cases of CMS, 271 cases were realized in crosses between species (Kaul, 1988) due to the interaction between domesticated genome and wild cytoplasm. Castor being a monotypic genus, inter generic hybridization with related genera within *Euphorbiaceae* family can be explored. Genetically pure, homogenous parental lines need to be used for making plant to plant hybridization. Wild species should be used as a female while the cultivated genome as a male. The anther morphology, pollen viability of all the F_1 plants need to be estimated and any plants with partial or full male sterility should be back crossed with the recurrent parent on a plant to plant basis to enhance the male sterility. The parents should be as diverse as possible to get the desirable CMS system.

Induced mutations: The CMS phenotype in majority of the cases originated due to spontaneous or induced mutations in the mitochondrial genome of the male fertile progenitors as a result of intra-or intermolecular recombination events. The mitochondrial genome rearrangements have generated chimaeric mtDNA sequences which in some cases result in generation of novel mitochondrial genes or lead to a modification of existing genes. These chimaeric genes are expressed as novel or modified polypeptides which, in an unknown fashion, are related.

Several chemical and physical mutagens were used for induction of CMS *viz.*, streptomycin sulphate, mytomycin-C in sunflower; acridine in wheat, EMS, X-rays in barley and ethidium bromide (EB) in groundnut (Zaveri, 2002). Since the frequency of mutations is very low, it is required to raise a large population for the expression and identification of the male sterile plants. Sodium azide (0.025% for 48 hrs) and streptomycin sulphate (500 mg/l, 24 hrs) induced male sterility in pigeon pea (Zaveri, 1998; Ariyanayagam *et al.*, 1993). The generations need to be continued to M_6 and M_7 for the desired frequency of stable CMS plants (Rao *et al.*, 1994).

Induction of CMS in genetic male sterile line: In genetic male sterility (GMS), male sterility is controlled by non-allelic single recessive gene and fertility restorer genes independently co-exist in the same genotype in a non-interactive state (Zaveri, 2002). Such GMS sources were also used to induce CMS un pigeonpea (Ariyanayagam *et al.*, 1993). The plant progenies which significantly depart from 1:1 fertile: sterile ratio in M_2 need to be identified. The magnitude of CMS may be low in even in M_4 or M_5 generation as the build up of the interaction between nucleus and cytoplasm is slow in such cases. Zaveri and Donga (1998) reported a true breeding CMS-67 developed from a GMS line, QMS 1 treated with sodium azide 0.025% for 48 hrs in M_{10} generation.

Alteration in transformation protocol: A new type of CMS ARG-3-M-1 in sunflower was discovered while making a sterile analogue of line M-C in CMS-ARG-3 using a novel procedure for obtaining CMS. During the transfer of line M-C-5 in CMS ARG-3 an alteration was provoked in CMS ARG-3, which was reflected on cytoplasmic genes responsible for pollen reproduction.

Implications of CMS system in castor: Commercial hybrid seed production in castor is dependant on a pistillate line, with completely female flowers and male line which is monoecious with male flowers at the base and female flowers at the top. The pistillate line is able to produce male flowers either genetically through sex revertants or through induction of interspersed staminate flowers (ISR) by environmental factors like high temperature (>32°C), nutrition, age of the plant, etc. (Shifriss, 1960, Lavanya, 2002, Lavanya *et al.*, 2006). In case of a CMS system, the pistillate line is completely female without any induction of male flowers while a male line should be completely male without any female flowers. Research efforts for CMS system in castor need to be directed towards the survival of a male line either through growth regulators or tissue culture or ratooning of the plant.

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Genetic variations and divergence studies in castor (*Ricinus communis* L.) genotypes

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Abstract

Studies on genetic variability, heritability, genetic advance and divergence analysis were carried out on 38 genotypes of castor. High phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were recorded for the traits *viz.*, days to 50% flowering, plant height up to primary raceme, number of nodes up to primary raceme, length of primary raceme, number of capsules in primary raceme, number of raceme/plant, single plant yield, 100 seed weight and oil content. All the traits under study had high heritability. High heritability coupled with high genetic advance was observed for days to 50% flowering, plant height up to primary raceme, number of nodes up to primary raceme length of primary raceme, number of capsules in primary raceme and single plant yield there is a potential possibility on improvement of these traits by applying single selection pressure. Among the genome type evaluated nine traits by two methods *viz..*, mean and scores, four genome types namely, LRES 17, TMVCH 1, SKP 24 and TMV 5 were found to be better than others. Hence these genotypes are suggested as potential parents for further breeding work.

Keywords: Castor, heritability, genetic advance, D^2 analysis

Introduction

Castor (*Ricinus communis* L.) has become a crop of major economic importance in India by virtue of its export trade, industrial use as a non drying oil. Castor oil is used for a number of industrial products. In any crop improvement programme, germplasm serves as a valuable source of base population, which offers much scope for further improvement. Primary aim of the breeder is to improve the available genotypes by evolving superior varieties. The success of hybridization and selection in any crop mainly depends on the diversity of the parents involved. The evaluation of genetic diversity is of considerable importance from the point of identifying suitable parents marshelling them in hybridization. An investigation was undertaken to estimate the morphological and quantitative variation existing among the diverse genotypes collected and to assess the genetic diversity among them.

Materials and methods

Thirtyeight castor genotypes were obtained from various germplasm banks in India. The field experiments were conducted in the Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai during the rainy season in 2004. The experiment was laid out in randomized block design with two replications. Each genotype was raised in two rows of 4.8m length adapting a spacing of 90cm between rows and 60cm between plants in the row. The following biometrical observations *viz.*, days to 50% flowering, plant height up to primary raceme, number of nodes up to primary raceme, length of primary raceme, number of capsules in primary raceme, number raceme/plant, single plant yield and oil content were recorded in five plants selected at random from the middle of the rows.

The analysis of variance for all the above traits was worked out. Phenotypic and genotypic variance were calculated (Johnson *et al.*, 1955), phenotypic and genotypic coefficient of variations were calculated (Burton, 1951). Heritability (Robinson *et al.*, 1949) and genetic advance (Johnson *et al.*, 1955) were estimated. Divergence among the populations were computed by the model of Mahalanobis D^2 statistics (Mahalanobis, 1928).

Results and discussion

Analysis of variance was carried out to partition the variance into its components. The analysis of variance of the nine traits revealed significant differences among the genotypes for the all the traits i.e., days to 50% flowering, plant height up to primary raceme, number of nodes up to primary raceme, length of primary raceme, number of capsules in primary raceme, number raceme/plants, single plant yield and oil content. Plant height up to primary raceme, single plant yield and length of primary raceme exhibited high PCV and GCV estimates. High PCV and GCV for plant height up to primary raceme, single plant yield and length of primary raceme were reported by Sevugaperumal (1995). Dhapke *et al.* (1992) recorded high GCV and PCV for length of primary raceme, while oil content and 100 seed weight had lower PCV and GCV. Little difference between PCV and GCV for nine traits indicated that the least role played by environment on these characters (Table 1). All the traits invariably possessed high heritability estimates. High heritability coupled with high GCV was noted for plant height up to primary raceme, length of primary raceme and single plant yield. Traits like number of capsules in primary raceme, number raceme/plants, number of nodes up to primary raceme, days to 50% flowering had high heritability along with high genetic advance as per cent of mean. All the traits except 100 seed weight and oil content for which GA per cent was moderate and low respectively (Table 2). Dhapake *et al.* (1992) reported day to 50% flowering had high heritability and genetic advance. Length of primary raceme had high heritability and genetic advance as recorded by Sevugaperumal *et al.* (2000).

Wide range of genetic divergence was reflected in the formation of six clusters by the 38 genotypes. Maximum and minimum intra cluster distances were recorded in cluster III (7 types) and cluster II (2 types), respectively (Table 3). The maximum intra cluster distance was observed between cluster V with cluster II and I. Hence, genotypes belonging to these different clusters may be involved in hybridization to obtain to desirable segregants. Minimum inter cluster distance was observed between clusters II and IV which explains that the genotypes in these clusters would have been evolved by similar evolutionary procedures though their origin were different. Among the different traits studied, single plant yield followed by length of primary raceme contributed much to the genetic diversity among the genotypes. Sevugaperumal *et al.* (2000) reported single plant yield contributed maximum genetic divergence. Days to 50% flowering and number of capsules in primary raceme contributed minimum towards genetic diversity (Table 4). Among the genome type evaluated nine traits by two methods *viz.*, mean and scores, four genome types namely, LRES 17, TMVCH 1, SKP 24 and TMV 5 were better than others. Hence, these genotypes are suggested as potential parents for further breeding work.

Table 1 Variability parameters for different characters in castor

Characters	Range		Grand mean	Variance		Coefficient of variation (%)		
	From	To		Genotypic (GV)	Phenotypic (PV)	Genotypic (GCV)	Phenotypic (PCV)	PCV-GCV
Days to 50% flowering	45.30	73.80	58.13	48.45	49.95	11.97	12.16	0.19
Plant height up to primary raceme(cm)	52.77	168.24	101.19	735.31	739.43	26.80	26.87	0.07
No. of nodes up to primary raceme	10.10	20.60	15.20	4.86	5.04	14.51	14.78	0.27
Length of primary raceme (cm)	20.83	48.64	31.95	58.30	58.33	23.89	23.90	0.01
No. of capsules in primary raceme	17.00	33.14	22.56	16.20	16.20	17.84	17.94	0.10
No. of racemes per plant	3.50	6.90	5.08	0.75	0.75	17.01	17.32	0.31
100 seed weight(g)	24.31	30.23	26.88	2.12	2.12	5.43	5.65	0.22
Oil content (%)	43.63	51.54	47.50	3.84	3.84	4.12	4.26	0.14
Single plant yield(g)	42.33	90.48	61.43	151.52	151.52	20.03	20.15	0.12

Table 2 Heritability, genetic advance and genetic advances as per cent of mean for different characters in castor

Characters	Heritability	Genetic advance	Genetic advance as per cent of mean
Days to 50% flowering	97.01	14.12	24.29
Plant height up to primary raceme(cm)	99.44	55.71	55.05
No. of nodes up to primary raceme	96.40	4.47	29.34
Length of primary raceme (cm)	99.93	15.72	49.21
No. of capsules in primary raceme	98.82	8.42	36.53
No. of racemes/plant	96.47	1.76	34.42
100 seed weight (g)	92.38	2.87	10.76
Oil content (%)	93.55	3.92	8.23
Single plant yield (g)	98.90	25.21	41.05

Table 3 Inter and intra cluster D^2 and D values (within parenthesis)

Clusters	I	II	III	IV	V	VI
I	3247.91	2002	3950.76	2299.18	6890.88	3368.79
	(956.99)	(44.75)	(62.86)	(47.95)	(83.01)	(58.04)
II		153.88	3009.86	1374.84	7105.27	2533.88
		(12.41)	(54.86)	(37.08)	(84.29)	(50.34)
III			4886.12	3082.07	6120.12	4078.84
			(69.90)	(55.52)	978.23)	(63.87)
IV				185.41	4257.35	1786.96
				(13.62)	(65.25)	(42.27)
V					3888.21	5630.47
					(62.36)	(75.04)
VI						3617.37
						(60.15)

Diagonal values indicate intra cluster values; Values in paranthesis indicate D values

Table 4 Cluster mean values for different characters in castor

Characters/ Clusters	Days to 50% flowering	Plant height up to primary raceme (cm)	No. of nodes up to primary raceme	Length of primary raceme (cm)	No. of capsules in primary raceme	No. of racemes / plant	100 seed weight (g)	Oil content (%)	Single plant yield (g)
I	54.41	119.14	15.00	28.12	22.83	5.12	26.57	47.48	66.05
II	63.30	103.14	14.95	25.33	19.85	5.10	26.17	46.29	52.95
III	55.88	88.16	14.11	29.83	21.46	5.56	26.65	47.21	63.70
IV	55.80	118.32	17.15	31.31	19.85	4.50	26.31	47.87	46.91
V	62.68	83.83	15.36	38.31	25.00	5.03	26.86	48.06	65.96
VI	56.87	113.68	15.63	30.73	21.26	4.53	27.42	47.21	54.36

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Heterosis for maturity and maturity related traits over seasons in castor (*Ricinus communis* L.)

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Abstract

The standard heterosis and heterobeltiosis was estimated in a Line x Tester, crossing programme involving five females and 14 males in castor. In the present study, diverse pistillate lines *viz.*, VP(NR), NES-6, NES-17, NES-19 and LRES-17 were used to study the extent of heterobeltiosis in F_1 hybrids nine maturity related traits *viz.*, plant height, number of nodes to primary raceme, days to flower initiation, days to 50% flowering on primary raceme, days to 100% flowering on primary raceme, days to 100% maturity on primary raceme, days to absolute maturity,

average internodal distance and Bartlett's Rate Index for yield. As many as 61 hybrids in S_1 and 62 hybrds in S_2 showed significant negative heterosis over standard check, GCH-4 for maturity related traits. Maximum number of crosses showed negative heterosis for nodes to primary raceme followed by plant height, days to 100% maturity on primary raceme, days to flower initiation on primary raceme, days to 50% flowering on primary raceme and days to 100% flowering on primary raceme. Eight out of 70 hybrids showed significant standard heterosis for yield and earliness. Four out of these eight hybrids *viz.*, VP-1(NR) x RG-374, NES-17 x RG-360, NES-17 x RG-374 and NES-17 x VP-1(M) had early maturity with high yield/plant.

Keywords: *Castor, heterosis, heterobeltiosis*

Introduction

Castor (*Ricinus Communis* L.) is one of the important non-edible oilseed crops of India. Castor plays an important role in our national economy by earning foreign exchange through export of castor oil. For any crop improvement programme, it is necessary to know the performance of a cross combination in comparison to the parents involved in the synthesis of hybrid. Commercial exploitation of heterosis in castor regarded as one of the major break through in the field of castor improvement. Castor is a highly cross pollinated crop and with the availability of 100% pistillate lines, heterosis has been successfully exploited in castor and the first castor hybrid GCH-3 (TSP-10RxJI-15) was released for general cultivation in Gujarat as early as 1968 (Gopani *et al.*, 1968). Castor hybrids have occupied 90% of the total cultivated areas of Gujarat (Anonymous, 1997). In Karnataka from 1989 on wards the area under castor hybrid has increased from zero to 20% of the from 1989 (Anonymous, 1997). Prior to 1989 in Karnataka, one of the main reasons for lack of spread of area under castor was the very tall and late maturing nature of the variety, which were under cultivation. Early maturing hybrids are needed to fit into the rainfed conditions. Most of the released castor hybrids for commercial cultivation mature in about 150 to 210 days under irrigated condition and 150 to 180 days under rainfed situations. There is an immediate need to identify hybrids, which can mature within 120-150 days with high bean yield potential for rainfed conditions and 150-180 days for irrigated conditions. Therefore, the present study was undertaken with the objective to identify early maturing hybrids with high productivity.

Materials and methods

Five commonly used pistillate line *viz.*, VP-1(NR), NES-6, NES-17, NES-19 and LRES-17 and 14 monocious lines *viz.*, VP -1(M), Aruna, 48-1 RG-202, RG-217, RG-358, RG-359, RG-360, RG-363, RG-374, RG-135, SH- 63, Bhagya and SH-41 were utilized for crossing to generate 70 hybrids. In Line x Tester analysis, the pistillate lines and testers were grown in a separate parental block adjacent to the F_1s block. The 70 hybrids synthesized, one commercial hybrid check i.e., GCH-4 along with 19 parents (5 lines and 14 testers) were evaluated in randomized complete block design with three replications over two years during rainy season at RRS, Raichur; UAS, Raichur. Each entry was grown in three rows of 10 dibbles/row. The distance between rows was 90 cm, while distance between plants was 60 cm. All the standard agronomic practices were followed to grow a good crop. The observations were recorded on five randomly selected plants in each replication for each genotype for maturity; maturity related and yield related characters.

Results and discussion

Nine earliness conferring characters *viz.*, plant height, number of nodes to primary raceme, days to flower initiation, days to 50%t flowering on primary raceme, days to 100% flowering on primary raceme, days to 100% maturity on primary raceme, days to absolute maturity, average internodal distance and Bartlett's Rate Index for yield were considered for the study. Among the maturity related traits, 47 and 52 hybrids for plant height in S_1 and S_2 respectively transgressed the better parental value for earliness which indicated the preponderance of over dominance.(*Table.1*). Majority of the hybrids transgressed the standard check values for earliness related traits *viz.*, plant height, days to flower initiation, days to 50% flowering on primary raceme, days to 100% flowering on primary raceme, days to 100% maturity on primary raceme, days to absolute maturity, nodes to the primary raceme which indicted preponderance of over dominance for the traits. Many of the earlier reports (Dangaria *et al.*, 1987; Chakrabarty, 1997 and Mahantashivayogayya and Kenchanagoudar, 2002) also indicated over dominance for plant height. However, the other characters like days to flower initiation, days to 50% flowering, days to 100% maturity on primary raceme and days to absolute maturity had nearly 40 hybrids showing significant better parent (BP) heterosis which indicated preponderance of over dominance for the characters studied. Similar results were also reported by Dangaria *et al.* (1987), Patel (1996) and Mahantshivayogayya and Kenchanagoudar (2002).

Heterosis for earliness was in general negative as indicated by the negative direction of better parent heterosis for days to maturity as well as its component characters, though the magnitude was not high. Similar results have been reported by Singh and Yadav (1984), Dangaria *et al.* (1987) and Chakrabarty (1997). Consistency in the extent and direction of heterosis in both the seasons for many of these maturity characters was observed except for average internal distance and nodes to the primary raceme. The percentage of heterosis ranged (Table.1) from 70.04 to -60.29 for plant height; 27.44 to -29.05 for days to flower initiation on primary raceme; 23.74 to -21.43 for days to 50% flowering on primary raceme; 24.93 to -24.01 for days to absolute maturity over the better parent across the two seasons S_1 and S_2. The percentage of heterosis ranged from 42.50 to -51.43 for plant height; 19.85 to -43.38 for days to flower initiation on primary raceme; 13.46 to -36.54 for days to 50% flowering on primary raceme; 0.21 to -38.53 for days to absolute maturity over the standard check, GCH-4 across the two seasons S_1 and S_2 (Table 1). Similar reports were also made by (Patel, 1991; Patel, 1994 and Patel, 1997).

Table 1 Number of hybrids showing significant and range of per cent heterosis over better parent and standard check for maturity related traits and yield across two seasons in castor

Characters	Seasons	Better Parent		Standard Check		Better parent		Standard check	
		+ve	-ve	+ve	-ve	+ve	-ve	+ve	-ve
Plant height	S_1	20	47	11	49	31.73**	-60.29**	42.50**	-48.89**
	S_2	16	36	07	52	70.04**	-41.43**	30.78**	-51.43**
Days to flower initiation	S_1	24	12	12	40	27.44**	-27.78**	19.85**	-43.38**
	S_2	29	15	05	46	22.12**	-29.05**	10.35**	-42.75**
Days to 50% flowering on primary raceme	S_1	29	09	08	42	23.74**	-21.43**	13.46**	-36.54**
	S_2	37	10	03	44	23.40	-20.30**	9.20**	-34.97**
Days to 100% flowering on primary raceme	S_1	35	09	09	36	21.93**	-13.74**	12.07**	-26.44**
	S_2	37	09	00	41	24.49**	-19.43**	3.30	-31.88**
Days to 100% maturity on primary raceme	S_1	40	05	00	51	15.84**	-10.30**	2.25	-21.72**
	S_2	23	11	00	52	11.69**	-13.47	1.83	-22.66**
Days to absolute maturity	S_1	25	23	00	61	24.93**	-20.95**	0.00	-36.62**
	S_2	19	27	00 -	62	17.65**	-24.01**	0.21	-38.53**
Nodes to the primary raceme	S_1	34	16	01	59	60.46**	-19.31**	8.75**	-43.88**
	S_2	28	03	00	50	68.70**	-13.03**	11.39*	-38.79**
Average internodal distance	S_1	64	01	37	14	91.90**	-11.62**	58.13**	-27.48**
	S_2	64	00	17	09	110.97**	-1.30	38.56**	-35.80**
Bartlett's rate of index for yield	S_1	56	5	63	01	25.61**	-9.27**	23.40**	-3.12**
	S_2	43	12	60	00	30.13**	-10.51**	32.27**	-1.37
Castor seed yield/plant	S_1	37	21	15	47	62.29**	-25.70**	63.34**	-31.95**
	S_2	49	11	20	40	85.66**	-22.10**	63.17**	-38.45**

Table 2 Per cent heterosis for the maturity related traits and yield across two seasons for highly productive crosses over better parent in castor

Crosses	Season	Plant height (cm)	Days to flower initiation on primary raceme	Days to 50% flowering on primary raceme	Days to 100% flowering on primary raceme	Days to 100% maturity on primary raceme	Days to absolute maturity	Nodes to the primary raceme	Average internodal distance (cm)	Bartlet's Rate of Index for yield (BRICY)	Castor seed yield/plant (g)
VP-1(NR) x RG-374	S_1	-27.83**	17.43**	17.12**	14.55**	3.87*	4.93**	-7.84**	20.33**	9.61**	41.07**
	S_2	-5.33	22.12**	22.70**	17.20**	2.32	3.38	-4.19	64.02**	15.49**	80.91**
NES-17 x RG -374	S_1	-31.40**	1.60	3.48	4.39	6.25**	4.80**	20.22**	27.30**	5.41**	26.77**
	S_2	-17.88**	6.38	2.85	11.55**	2.84	6.00**	15.89*	91.61**	1.31	63.95**
NES-17 x VP-1(M)	S_1	4.11**	17.45**	18.75**	18.13**	15.84**	19.20**	1.10	36.39**	0.13**	62.29**
	S_2	9.54	12.79**	15.00**	22.45**	6.89**	12.53**	1.77	52.90**	-5.00	85.66**
NES-19 x RG -374	S_1	-29.48**	11.03**	14.89**	9.62**	9.67**	10.47**	60.46**	9.13**	5.10**	-7.96**
	S_2	-24.46**	16.54**	10.20**	9.02**	4.86*	8.91**	39.62**	38.27**	8.16	62.64**
NES-17 x RG -360	S_1	-49.91**	-19.05**	-16.67**	-13.13**	-2.09	-6.94**	-10.70**	26.51**	0.53	32.51**
	S_2	-13.35**	-10.42**	-7.86**	1.37	-3.23	-6.79**	21.80**	83.87**	11.03**	54.61**
NES-17 x RG -358	S_1	-41.52**	16.67**	14.58**	13.76**	13.45**	12.26**	-11.29**	41.47**	3.96**	40.99**
	S_2	-21.76**	18.38**	18.56**	24.49**	8.50**	15.40**	4.77	110.97**	0.26	39.53**
VP-1(NR) x RG-359	S_1	-24.92**	13.64**	13.68**	11.51**	1.93	-5.61**	-10.83**	44.20**	1.67	33.64**
	S_2	-8.73**	18.32**	23.40**	19.11**	2.71	0.68	2.65	64.94**	-1.26	40.89**
VP-1(NR) x 48-1	S_1	8.44**	7.63**	13.01**	9.09**	5.41	0.22	-2.14	52.18**	12.46**	12.31**
	S_2	45.93**	3.80	12.06**	11.47**	1.93	-1.13	12.39*	67.38**	12.90**	41.42**
LRES-17 x RG-374	S_1	-32.66**	4.41	6.70**	10.50**	9.64**	6.81**	-8.78**	51.71**	7.72**	4.31**
	S_2	-33.54**	11.36**	14.58**	15.82**	10.08**	6.99**	-13.03*	34.01**	5.16*	36.92**
VP-1(NR) x VP-1(M)	S_1	10.65**	21.98**	19.17**	18.18**	5.03**	2.24	0.00	15.31**	9.17**	12.47**
	S_2	0.10	19.83**	18.45**	15.29**	2.71	0.22	4.80	17.32	17.38**	27.50**
LRES-17 x SH-63	S_1	-34.61**	0.73	2.01	6.80**	6.83**	1.88	-15.79**	72.27**	15.83**	19.77**
	S_2	-28.12**	1.52	6.94*	9.49**	6.05**	0.47	-7.14	29.65**	6.03**	36.88**

**, * = Significant at 5% and 1% level, respectively

Highly productive (Table 2) crosses in the present study were, VP-1 (NR) x RG-374 which exhibited negative significant values for plant height, nodes to the primary raceme over better parent while, negative values we re observed for days to absolute maturity and nodes to primary raceme over standard check, GCH-4 .The hybrid, NES 17 x RG-374 exhibited negative significant values for plant height over better parent and negative significant values for days to flower initiation, days to 50% flowering, days to 100% flowering and days to absolute maturity, nodes to primary raceme over the standard check (Table 3). *It is suggested to employ reciprocal recurrent selection or recurrent selection for specific combining ability* for improving the populations with respect to earliness so as to fit into rainfed conditions.

Table 3 Per cnt heteosis for the maturity related traits and yield across two seasons over standard check for highly productive crosses in castor

Crosses	Seasons	Plant height (cm)	Days to Flower initiation	Days to 50% flowering	Days to 100% flowering	Days to 100% maturity	Days to Absolute maturity	Nodes to the primary raceme	Average internodal distance (cm)	Bartlett's Rate of Index for yield (BRICY)	Castor seed yield/plant (g)
VP-1(NR) x RG-374	S_1	1.11	13.97**	9.62**	8.62**	0.75	-2.63	-1.77	2.96	3.54**	63.34**
	S_2	22.19	10.35**	6.15*	1.09	-2.58	-0.65	7.15	13.98	7.76**	63.17**
NES-17 x RG -374	S_1	-3.89	-5.88**	-4.49*	-4.02	-4.49**	-13.82**	-6.12	2.54	13.33**	46.78**
	S_2	5.99	-8.28**	-11.65**	-9.89**	-6.62**	-12.12**	-16.90**	25.85**	17.35**	47.87**
NES-17 x VP-1(M)	S_1	-15.65**	8.82**	9.62**	8.62**	-4.12**	-1.97	-21.05**	6.97*	7.66**	33.13**
	S_2	-26.70**	-2.75	-1.21	-1.10	-2.94	-6.71**	-27.02**	0.42	10.04**	35.12**
NES-19 x RG -374	S_1	-1.21	3.68	3.85	-1.72	-2.25	-2.85*	-12.70**	11.20**	0.71	6.57**
	S_2	-2.49	-2.75	-7.36*	-7.15	-4.79**	-4.76*	-6.33	4.87	0.91	46.69**
NES-17 x RG -360	S_1	-28.98**	-25.00**	-23.08**	-20.11**	-13.11**	-23.46**	-30.26**	1.90	8.08**	21.06**
	S_2	5.02	-22.76**	-20.85**	-18.13**	-12.13**	-22.73**	-12.66	20.76**	28.61**	33.30**
NES-17 x RG -358	S_1	-21.11**	8.09**	5.77*	4.60*	1.12	-7.68**	-30.72**	13.95**	11.77**	23.02**
	S_2	-11.71**	2.07	1.84	0.54	-1.48	-4.33*	-24.87**	38.56**	16.13**	24.28**
VP-1(NR) x RG-359	S_1	10.74**	10.29**	6.41**	5.75**	-1.12	-7.68**	-10.06**	23.47**	3.83**	22.88**
	S_2	12.26**	6.91*	6.76*	2.75	-2.21	-3.25*	-2.09	14.62	7.00**	24.38**
VP-1(NR) x 48-1	S_1	30.74**	3.68	5.77*	3.45	2.25	-1.97	2.17	30.23**	1.13	14.15**
	S_2	23.98**	-6.21	-3.06	-3.86	-2.94	-4.98*	7.15	15.31*	15.82**	25.95**
LRES-17 x RG-374	S_1	-5.65**	-4.41	1.92	2.87	2.25	-0.22*	-8.36**	2.96	11.20	20.77**
	S_2	-14.22**	1.39	1.23	0.54	0.36	-0.65	-12.66**	-2.33	2.28	23.50**
VP-1(NR) x VP-1(M)	S_1	2.04	18.38**	11.54**	12.07**	1.87	0.00	3.48	-1.27	1.27	4.20**
	S_2	-16.37**	8.28**	2.47	-0.56	-2.21	-3.68*	8.86	-23.94**	12.02**	12.56**
LRES-17 x SH-63	S_1	-5.00**	-1.47	-2.56	-0.57	-0.37	-4.82**	-15.79**	16.91**	11.06**	8.53**
	S_2	-15.83**	-7.57*	-5.52	-4.94	-3.31	-6.71**	-12.66**	-5.51	7.00**	-15.40**

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Comparative assessment of yield gain with castor hybrids over varieties in relation to fertilizer input

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Abstract

Field experiments were carried out from 2007-08 to 2009-10 under the All India Coordinated Research Project on Castor at seven locations *viz.*, Bawal, Hiriyur, Junagadh, Kanpur, Mandor, S.K. Nagar and Yethapur to study the comparative assessment of yield gain with castor hybrids over varieties in relation to different fertilizer input. Three hybrids along with two varieties of castor were evaluated under four levels of fertilizer input. The average results indicated that castor variety 48-1 yielded as much as the hybrid at four locations namely, Bawal, Hiriyur, Junagadh and Kanpur while a local variety TMV-5 performed as good as hybrids at Yethapur. However, at Mandor and S.K. Nagar under irrigated conditions on Aridisols, the hybrids were superior to varieties. There was linear significant response up to 150% recommended dose of fertilizer (RDF) at most of the locations except at Bawal, Yethapur and Junagadh where the response was restricted to only 100% RDF. The interaction effect was not significant at most of the locations except for one year at Junagadh and two years at Hiriyur where high yielding genotype responded up to 150% RDF.

Key words: Castor, hybrids, fertilizer response, varieties

Introduction

Commercial exploitation of heterosis has led to breakthroughs in productivity of several crops including castor. After the development of first castor hybrid GCH-3 during 1976, a large number of hybrids have been released in the country. Simultaneously varietal development is also continuing leading to release of 13 varieties. Currently, more than 75 to 80% of the castor area in the country is planted with hybrids. Although hybrids generally have higher yield potential than varieties (DOR, 2010), farmers continue to prefer some of the latest high yielding varieties realizing as high yields as hybrids. Higher productivity of hybrids naturally demands higher fertilizer input. The present studies were therefore, carried out to study the comparative assessment of yield gain with castor hybrids over varieties under different levels of fertilizer input.

Materials and methods

Field investigations were carried out under the All India Coordinated Research Project on Castor during 2007-08 to 2009-10 at seven locations, *viz.*, Bawal (Haryana), Hiriyur (Karnataka), Junagadh (Gujarat), Kanpur (Uttar Pradesh), Mandor (Rajasthan), S.K. Nagar (Gujarat) and Yethapur (Tamil Nadu). The soils were Aridisols at Bawal and Mandor; Vertisols at Hiriyur and Junagadh; Entisoils at Kanpur and S.K. Nagar, Alfisols at Yethapur. The pH in the experimental soils ranged from 7.9 -8.5 at Bawal, 8.3-8.7 at Hiriyur, 7.8 at Junagadh, 7.9 at Kanpur. 8.1-8.6 at Mandor, 7.5-8.5 at S.K. Nagar and 6.7 at Yethapur. The available N, P and K status were low, low-medium and medium-high at Bawal; medium for all the nutrients at Hiriyur; medium, high and high at Junagadh; low, medium and low at Kanpur; low, medium and medium at Mandor; low, medium-high and medium at S.K. Nagar and medium, low and high at Yethapur, respectively. The treatments comprised of combinations of four levels of fertilizer (0, 50, 100 and 150% of recommended NPK) and five castor genotypes - two varieties (local and high yielding variety) and 3 hybrids (local and two nationally released high yielding hybrids). The treatments were arranged in a randomized block design with three replications. The experiment was conducted under irrigated conditions at Bawal, Junagadh, Kanpur, Mandor and S.K. Nagar and under rainfed conditions at Hiriyur and Yethapur. The recommended dose of fertilizers were 40:40:0 and 75:50:0 kg N, P_2O_5 and K_2O/ha under rainfed and irrigated conditions respectively. The crop was planted with a spacing of 90 cm x 60 cm under rainfed conditions and 120 cm x 60 cm under irrigated conditions. Full dose of P and K and half of N as per the treatment was applied at planting and the remaining N was top dressed 6 weeks later under rainfed conditions. Under irrigated conditions, the remaining half of N was top dressed twice in two splits after first and second picking. Standard management practices were followed to grow the crop. The seed yield was recorded after each picking at 90, 120, 150 and 180 days after planting under rainfed conditions and upto 210 days under irrigated conditions. Total seed yield was calculated by totaling the yield at different pickings. The experiment was carried out for two years at Bawal and Mandor and three years at all the other centres and pooled seed yield data is presented.

Results and discussion

Performance of hybrids and varieties: The differences in mean seed yield among genotypes were significant at all the locations except at Bawal (Table 1). At Mandor under irrigation, the hybrid GCH-4 recorded the highest seed yield (3727 kg/ha) which was at par with hybrid DCH-177 (3665 kg/ha) but significantly superior to hybrid RHC-1 (3137 kg/ha), varieties 48-1 (2797 kg/ha) and DCS-9 (3236 kg/ha). At S.K. Nagar under irrigation, both hybrids DCH-177 (3440 kg/ha) and GCH-7 (3343 kg/ha) recorded significantly higher seed yield than the hybrid GCH-4 (3061 kg/ha) and both the varieties (2854 to 2913 kg/ha). At Hiriyur under rainfed conditions, the variety 48-1 (1468 kg/ha) recorded the highest seed yield which was at par with that recorded by hybrid DCH-177 hybrid (1437 kg/ha) but significantly higher than all other genotypes (1120 to 1209 kg/ha). At Yethapur under rainfed conditions, both hybrids YRCH-1 (1486 kg/ha) and GCH-4 (1430 kg/ha) recorded significantly higher seed yield than the variety 48-1 (1238 kg/ha) but at par with the local variety TMV-5 (1376 kg/ha). At Junagadh, the variety 48-1 (2668 kg/ha) recorded at par seed yield with all the hybrids (2740 to 2847 kg/ha) and was significantly superior to other variety DCS-9 (2205 kg/ha). More or less similar results were recorded at Kanpur where variety 48-1 (1951 kg/ha) was at par with both the hybrids (1847 to 1983 kg/ha) but superior to variety DCS-9 (1617 kg/ha). The results thus clearly indicate that some of the varieties had almost same yield potential as hybrids both under rainfed and irrigated conditions.

Response to fertilizer: The differences in seed yield of castor among fertilizer levels were significant at all the seven centres (Table 2). At Mandor, S.K. Nagar, Hiriyur and Kanpur, there was significant linear response upto 150% RDF while at Bawal, Yethapur and Junagadh, the response was significant only up to 100% RDF. The response to applied nutrients is generally governed by the status of available nutrients in the soil (Hegde, 1998) and significant response to fertilizer application is expected on these soils.

Interaction: The interaction between castor genotypes and fertilizer levels were significant only at Hiriyur (2 out of 3 years) and Junagadh (1 out of 3 years) although no clear trend in the response was observed. The high yielding genotypes responded to higher levels of fertilizer as compared to low yielding genotypes which had lower response to fertilizer.

Table 1 Performance of different hybrids and varieties of castor

Hybrid/Variety	*Total seed yield (kg/ha)*						
	Mandor (1)	Bawal (2)	S.K. Nagar (3)	Hiriyur (3)	Yethapur (3)	Junagadh (3)	Kanpur (3)
Hybrids							
GCH-4	3727	2050	3061	1209	1430	2756	1983
DCH-177	3665	2149	3440	1437	1355	2847	1847
RHC-1	3137	2386	-	-	-	-	-
GCH-7	-	-	3343	-	-	2740	-
DCH-32	-	-	-	1120	-	-	-
TMVCH-1	-	-	-	-	1486	-	-
Varieties							
48-1	2797	2146	2913	1468	1238	2668	1951
DCS-9	3236	2188	-	1149	-	2225	1617
GC-2	-	-	2894	-	-	-	-
TMV-5	-	-	-	-	1376	-	-
SEm±	99	66	100	47	59	64	28
CD (P=0.05)	285	NS	288	138	154	185	84

Figures in parentheses indicate the number of years of data used to calculate the mean.

Table 2 Response of castor hybrids/varieties to fertilizers

Fertilizer level	Total seed yield (kg/ha)						
	Mandor (1)	*Bawal* (2)	*SK Nagar* (3)	*Hiriyur* (3)	*Yethapur* (3)	*Junagadh* (3)	*Kanpur* (3)
Control (No fertilizer)	2627	1851	2359	1011	1135	2257	1090
50% RDF	3114	2108	2917	1226	1234	2634	1774
100% RDF	3542	2360	3427	1312	1567	2919	2084
150% RDF	3967	2414	3796	1557	1621	2936	2451
SEm±	93	67	109	41	62	75	21
CD (P=0.05)	323	232	376	155	185	260	77

Figures in parentheses indicate the number of years of data used to calculate the mean.

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Yield prediction modelling in castor based on canopy architecture, dates of sowing and genotypes

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Abstract

The study on the effect of nipping and dates of sowing on canopy structure, growth, yield and disease infestation of castor genotypes was carried out at Bengaluru during rainy seasons of 2008-2009. The combined influence of growth and yield parameters on seed yield of castor were studied through developing multiple linear regression models (MLR). Among the 9 models developed, model III was found better when seven significant yield parameters were regressed together against yield, contributing 91% of the yield. MLR model VI (Y= -2288.91 -335.42 disease score +52.85 chaffiness % +1360.77 harvest index +20.21 crop duration in days) was the best when only four important yield contributing parameters were regressed together with yield, sharing 88% of the yield.

Key words : Multiple linear regression models, date of sowing, nipping, castor

Introduction

Castor (*Ricinus communis* L.) is an important non edible oil seed crop in drylands of Karnataka. However, the average production per hectare is far below the country's productivity. Several reasons could be attributed for low productivity of castor in Karnataka. Among them, low yielding varieties, cultivation on marginal lands, poor fertilization, disease, pest attack and uneven time of sowing are the major ones. Further, castor is perenial in nature with indeterminate growth habit. Hence, it put forth lot of unwanted vegetative growth particularly under early sowing with numerous spikes at primary, secondary, tertiary and quaternary branches leading to uneven source-sink relationship. Prolonged humid conditions coupled with continuos rainfall with cloudy weather leads to severe infestation of spikes with *Botrytis* disease particularly under uninhibited branching, canopy overlaping and shading. Many a times the infestation seems to be devastating to the crop (Shivaramu and Krishna Murthy, 2008). Therefore, an attempt was made to maintain few branches *vis-à-vis* spikes with controlled canopy growth and reducing the unwanted vegetative growth through periodical staggering. Based on the results obtained, the correlation, regression and multiple linear regression models were developed to study the magnitude and type of association of yield with its component characters and for predicting/ forcasting the yield of castor.

Materials and methods

In 2008-2009, a field experiment was conducted with two genotypes *viz.*, GCH-4 hybrid and Kranthi variety under 3 dates of sowing *viz.*, early sown May 30th, June 30th and late sown July 30th with 2 levels of nipping (no nipping and periodical staggered nipping) in red sandy clay loam. The design of the experiment was factorial randomised complete block design with three replications. The crop was sown at a wider spacing of 120 cm x 45 cm and fertilized with FYM 5 t/ha and 38:38:25 kg of NPK/ha. All other agronomic practices were carried out as per the recommended package of practices. The severity of the *Botrytis* disease was assessed by adopting 1-9 scale (Subramanyam *et al.*, 1982). After harvesting the spikes and capsules were dried, threshed and seed yield in each plot was recorded and analyzed statistically. Correlation matrix and regression equations *viz.*, simple linear, quadratic and multiple linear were computed (Panse and Sukhatme, 1967). Further using step down regression analysis by least square technique (Barrie *et al.*, 1986), the less important growth and yield parameters were dropped one after another and the MLR models with seed yield were developed. The best models were chosen based on the criteria (a) R^2 value should be higher and significant at or below 5% level of significance, (b) more number of independent variables in the model should also be significant at or below 5%, (c) the S.E of 'a', S.E of 'y' estimate and the index of multi-co-linearity should be comparatively low and (d) the intercept 'a' should also be significant at or below 5%.

Results and discussion

Yield and yield attributes: Castor being a long duration crop sown early in May utilizing the pre-monsoon shower and nipping has given highest yield (3108 kg/ha) followed by June sowing with nipping (2334 kg/ha). However, under non-nipping conditions even with early sowing could be able to give yield of 1692 kg/ha which was significantly inferior to nipping with early sowing. The effect of nipping was not conspicuous under late sown conditions (July 30th) although nipping has given significantly higher yield (991 kg/ha) compared to non-nipping (750 kg/ha) (Table 1).

The increased seed yield to the extent of 183% due to nipping and early sowing was attributed to increased spike length, number of capsules/spike, reduction in the disease infestation and due to decreased %age of chaffiness. These yield attributes showed superior performance because of reduced and controlled branching, decreased canopy overlapping leaf area inded (LAI) of 0.48 as against 2.25 in non-nipping at 150 DAS), increased light penetration into the crop canopy. Thus, the modified canopy architecture due to nipping has brought down the disease incidence of *Botrytis* as it could not find a congenial canopy micro-climate. Whereas, non-nippping even with early sowing (May 30th) could be able to give a maximum yield (1692 kg/ha) which was significantly inferior to nipping treatments under May (3108 kg/ha) and June (2334 kg/ha) date of sowing.

The poor yield performance of non-nipping treatments irrespective of dates of sowing was mainly attributed to reduced spike length, number of capsules/spike, test weight, and increased chaffiness %age which in turn were due to severe *Botrytis* infestation (5.95 to 8.41 rating). Besides, the poor values of the above yield contributing parameters, the uncontrolled vegetative growth in terms of indiscriminate branching (14.37 to 26.72) and canopy overlaping (LAI of 0.89 to 2.25 at 150 DAS) favoured the micro-climate for infestation of the *Botrytis* disease. These results are in conformity with the findings of Shivaramu and Krishna Murthy (2008).

Correlation and regression studies: The correlation matrix of growth and yield parameters among themselves and on seed yield of castor was indicated with the following salient points. Seed yield of castor was significantly and possitively correlated with plant hieght (r= 0.49), spike length (r = 0.63), number of capsules/spike (r = 0.69), test weight (r = 0.62), oil content (%) (r = 0.70), harvest index (r = 0.73) and days to maturity (r= 0.73). The significantly and negitively correlated parameters with seed yield were found to be disease infestation rate (r = -0.77) and chaffiness %age (r = -0.76). The leaf area (cm^2), number of branches/plant, and number of spikes/plant did not significantly influence the seed yield of castor either positively or negitively.

The relationship between growth and yield parameters, disease incidence and days to maturity was quantified through establishing regression equations. Among the significant parameters, plant height, disease scoring, chaffiness (%) and oil content showed significant linear and quadratic relationships. Whereas, spike length, number of capsules/spike, test weight, harvest index and duration of the crop had significant linear relationship with seed yield of castor.

Disease incidence alone could be able to influence the seed yield of castor to the extent of 65% followed by chaffiness (64%) and oil content (55%) as replicated from their respective R^2 values.

Multiple linear regression models: Besides looking at the individual effects of growth and yield parameters, the combined influence of these parameters on seed yield of castor were studied through developing MLR models (Table 2). When all the nine significant parameters were regressed against yield, the R^2 value was worked out to be 0.91 in model-I, indicating 91% of yield contribution by these parameters. However, model-III with only 7 significant yield parameters, the R^2 value was on par with model-I (0.91) indicating the superiority of former when compared to the latter. MLR model-VI (Y= -2288.91 - 335.42 disease score + 52.85 chaffiness % + 1360.77 harvest index +20.21 crop duration in days) was the best when only four important yield contributing parametrs were regressed together with yield, sharing to the extent of 88% of the yield. Disease score was the sole yield deciding factor to the extent of 59% as seen in the model-IX. However, one can use any of the developed models either for determining the yield, for judging the yield or for predicting/ forcasting the yield of castor.

Table 1 Yield parameters and yield of castor genotypes as influenced by effect of nipping and dates of sowing

Treatments		No. of spikes/ plant			Mean spike length (cm)			No. of capsules/spike			Test weight (g)			Seed yield (kg/ha)		
Genotypes (G)	Date of sowing (D)	Nipping (N)														
		N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
G_1	D_1	18.54	8.32	13.43	26.38	48.50	37.44	28.08	60.67	44.38	25.60	27.10	26.35	1487	2873	2180
	D_2	12.99	6.43	9.71	24.55	45.08	34.82	25.60	56.88	41.24	24.17	26.40	25.28	1080	2109	1595
	D_3	7.99	3.66	5.83	22.24	43.50	32.87	22.78	52.91	37.84	23.10	25.87	24.48	674	935	804
	Mean	13.17	6.14	9.66	24.39	45.69	35.04	25.49	56.82	41.15	24.29	26.46	25.37	1080	1972	1526
G_2	D_1	20.42	9.47	14.95	37.62	65.66	51.64	39.01	75.84	57.42	28.50	30.53	29.52	1898	3344	2621
	D_2	14.99	6.99	10.99	34.72	60.68	47.70	36.78	70.80	53.79	27.10	29.37	28.23	1337	2559	1948
	D_3	9.99	4.21	7.10	31.58	58.11	44.85	32.44	66.36	49.40	25.23	28.33	26.78	826	1047	936
	Mean	15.13	6.89	11.01	34.64	61.48	48.06	36.08	71.00	53.54	26.94	29.41	28.18	1354	2317	1835
Mean of D_1		19.48	8.89	14.19	32.00	57.08	44.54	33.55	68.25	50.90	27.05	28.82	27.93	1692	3108	2400
Mean of D_2		13.99	6.71	10.35	29.64	52.88	41.26	31.19	63.84	47.51	25.63	27.88	26.76	1209	2334	1771
Mean of D_3		8.99	3.94	6.46	26.91	50.80	38.86	27.61	59.63	43.62	24.17	27.10	25.63	750	991	870
	Mean	14.15	6.51		29.52	53.59		30.78	63.91		25.62	27.93		1217		

Sources	SEm +	CD (P=0.05)	SEm +	CD (P=0.05)	SEm +	CD (P=0.05)	SEm +	CD (P=0.05)	SEm +	CD (P=0.05)
Date of sowing (D)	0.93	2.86	0.86	2.66	0.86	2.65	0.40	1.25	24	75
Nipping (N)	0.76	2.34	0.71	2.17	0.70	2.17	0.33	1.02	20	62
Genotype (G)	0.76	NS	0.71	2.17	0.70	2.17	0.33	1.02	20	62
D x N	1.31	NS	1.22	NS	1.22	NS	0.57	NS	35	107
D x G	1.31	NS	1.22	NS	1.22	NS	0.57	NS	35	107
N x G	1.07	NS	1.00	NS	0.99	NS	0.47	NS	28	NS
D x N x G	1.86	NS	1.73	NS	1.72	NS	0.81	NS	49	NS

D_1: 30th May 2008; D_2: 30th June 2008; D_3: 30th July 2008; G_1: Kranthi Variety; G_2: GCH-4 Hybrid; N_1: Non-nipping; N_2: Nipping (periodical staggered nipping); NS: Nonsignificant; DAS: Days after sowing

Table 2 Multiple linear regression coefficients of yield parameters against yield (kg/ha) of castor in different models

Parameters	Model No								
	I	II	III	IV	V	VI	VII	VIII	IX
Plant height (cm)	-3.16								
Disese score (0-9)	-118.86	-162.29	-175.32	-223.98	-320.01*	-335.42**	-113.28	-206.65	-258.18**
Spike length (cm)	-16.56	-24.66	-27.76						
No. of capsules/spike	39.81	42.81*	43.08*	12.32					
100 seed weight (g)	-26.00	-20.74							
Chaffiness %	40.05	46.89	48.89*	47.21	52.80*	52.85*	-13.89	-12.39	
Oil %	109.02	117.62	103.41	84.09	124.04				
Harvest index	607.83	773.80	788.80	1106.52	1250.93*	1360.77*	1515.52		
Duration (days)	25.82**	21.86**	21.48**	20.38**	18.44**	20.21**			
a	-8840.26**	-8826.95**	-8529.74**	-6993.51*	-7452.18*	-2288.91**	1891.45*	2886.17**	2937.32**
SE of a	3183.34	3137.19	3041.25	2978.90	3019.13	640.54	719.50	272.42	203.97
SE of Y	300.39	296.05	292.10	300.60	306.35	316.33	563.82	574.13	566.33
R^2	0.9109**	0.9102**	0.9093**	0.9005**	0.8931**	0.8823**	0.6140**	0.5873**	0.5862**

* MLR model VI (Y= -2288.91 -335.42 disease score +52.85 chaffiness % +1360.77 harvest index +20.21 crop duration in days) was the best when only four important yield contributing parametrs were regressed together with yield, sharing 88% of the yield.

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Productivity potential and profitability of castor hybrids over varieties in relation to fertilizer input

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Abstract

Field experiments were conducted at C.S. Azad University of Agriculture and Technology, Kanpur during rainy season of 2008 and 2009 to assess the performance of castor hybrids over varieties at different levels of fertilizer input revealed that with increase in fertilizer dose from no fertilizer through 150% recommended dose of fertilizer (RDF), there was linear increase in productivity, the significantly maximum being with 150% RDF in both the years. Among the genotypes, variety 48-1 out yielded the rest of the genotypes. In production potential, the genotypes were in the order of 48-1, GCH-4, DCH-177 and DCS-9. Application of 150% RDF gave maximum gross returns, net returns and benefit-cost ratio followed by 100% RDF. Among the test genotypes, 48-1 and GCH-4 accrued more gross returns, net returns, and B:C ratio than DCH-177 and DCS-9.

Keywords: Castor hybrids, genotypes, economics, fertilizers

Introduction

Castor (*Ricinus communis* L.) is one of the ancient oilseed crops of the world with diversified uses (Hegde *et al.*, 2003). India is one of the primary centres of origin of castor and dominates world castor production accounting for 53% of area and 70% of production. Castor's productivity in India is higher (1392 kg/ha) than the world average (1037 kg/ha). Extensive breeding efforts have resulted in release of some excellent varieties and hybrids (Kumar *et al.*, 2009). Oilseeds being energy rich crops require high amount of nutrients for their production. Inadequate or imbalanced supply of nutrients has been found as one of the critical constraints limiting oilseeds production. Castor respond to major nutrients, particularly to nitrogen and phosphorus together rather than singly (Patel *et al.*, 2007). Agro-climatic conditions of Uttar Pradesh are quite suitable for castor cultivation (Srivastava and Chandra, 2009). Thus, the present study was conducted to find out the suitability of castor hybrids and varieties at different levels of fertilizer input under irrigated conditions of Uttar Pradesh during rainy season.

Materials and methods

A field experiment was carried out at Chandra Shekhar Azad University of Agriculture & Technology, Kanpur during the rainy season of 2008 and 2009 to compare the performance of castor hybrids over varieties at different levels of fertilizer input under irrigated conditions of Uttar Pradesh. The soil of the experimental field was sandy loam in texture, with pH 7.9, low in organic carbon (0.36%), low in available phosphorus (16.2 kg /kg) and medium in available potash (170 kg/ha). The experiment comprised of four main plot treatments of fertilizer levels viz., 0, 50%, 100% and 150% recommended dose of fertilizer (RDF) and four sub plot treatments of genotypes viz., 48-1, DCS-9, GCH-4 and DCH-177 was laid out in a split plot design and replicated three times. The RDF for castor is 50 kg N, 25 kg P_2O_5 and 15 kg K_2O/ha and were applied as per treatment in the form of urea, diammonium phosphate and muriate of potash. Half of N with full dose of P and K was applied as basal, and the remaining half nitrogen was top dressed in two equal splits at 30 and 45 days after sowing. Seeds were treated with carbendazim @1g/kg of seeds to protect from seed born diseases. The crop was sown on 29 July, during both the years. Seeds were dibbled @ 2 seeds/hill at a depth of 4-5 cm in the rows 90 cm apart keeping 60 cm plant spacing. All the recommended cultural practices and required appropriate plant protection measures were applied to grow a good crop. Capsules were harvested in three pickings manually based on physiological maturity. The crop received a rainfall of 774.6 mm and 745.7 mm during crop season in 2008 and 2009, respectively.

Results and discussion

Effect of fertilizer: It was observed that there was significant linear enhancement in seed yield with increase in fertilizer dose from 0 through 150% RDF during both the years (Table 1). Application of 150% RDF recorded significantly higher seed yield than lower doses while no fertilizer application produced significantly lowest seed yield in both the years. The superior performance of crop with higher doses could be attributed to better plant growth, more number of branches, longer spike and more number of capsules/spike. Similar increase in castor yields due to 150% RDF were also reported from Karnataka and Gujarat (DOR, 2008). Mathuria and Modhwadia (1993) advocated that better nutrition could have resulted in more number of spikes/plant and capsules/spike.

Performance of genotypes: Among the genotypes, 48-1 variety out yielded the rest of the genotypes though GCH-4 hybrid was the next best genotypes in both the years. The performance of DCH-177 hybrid was better than DCS-9 variety. The superior performance of 48-1 variety was due to better plant height, more branches/plant, more spikes/plant, lengthy spikes and more capsules /spike as compared with other genotypes.

Economic evaluation: Economics analysis showed that application of 150% RDF cost accrued higher gross returns, net returns and benefit-cast (B:C) ratio than the lower dose. Among the genotypes, 48-1 variety gave higher gross returns, net returns and B:C ratio than rest of the genotypes during both the years.

Table 1 Comparative study of castor hybrids and varieties at different levels of fertilizers

Treatment	Plant height (cm)		Branches/ plant		Spikes/ plant		Spike length (cm)		Capsules/ spike		Total seed yield (kg/ha)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Fertilizer levels												
No Fertilizer	73.0	84.4	4.3	4.0	5.1	5.2	52.1	48.2	60.6	58.5	1233	1297
50% RDF	83.1	98.2	5.2	4.9	6.2	6.1	61.9	56.4	67.8	68.2	1927	1883
100% RDF	92.5	106.2	5.7	5.6	6.9	7.0	67.1	63.3	75.3	75.6	2272	2252
150% RDF	96.7	110.7	6.1	6.0	7.3	7.4	70.7	69.1	80.4	80.9	2810	2516
SEm±	0.9	1.5	0.1	0.1	0.1	0.1	1.0	0.7	0.9	0.8	24	20
CD (P=0.05)	2.9	5.3	0.3	0.3	0.3	0.4	3.4	2.5	3.1	2.8	85	69
Genotypes												
48-1	94.1	108.5	5.9	5.7	7.3	7.4	68.6	65.5	78.3	77.1	2332	2217
DCS-9	80.9	92.0	4.9	4.7	5.8	5.8	59.3	52.8	67.3	66.1	1824	1730
GCH-4	87.4	102.3	5.4	5.2	6.3	6.4	63.4	61.4	70.3	71.0	2106	2061
DCH-177	83.1	96.8	5.1	4.8	6.0	6.1	60.5	57.3	68.2	69.0	1979	1940
SEm±	1.4	2.0	0.1	0.2	0.1	0.2	1.1	1.6	1.3	1.4	27	27
CD (P=0.05)	4.0	5.8	0.3	0.4	0.3	0.5	3.3	4.7	3.9	4.1	80	78

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Studies on weed management in castor under rainfed conditions

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Abstract

A field experiment was conducted during the rainy season of 2005 in the research farm of Regional Agricultural Research Station (ANGRAU), Palem, Mahaboobnagar dist., Andhra Pradesh to study the effect of different weed management practices on growth, yield and economics of castor grown under rainfed conditions. The results indicated maintaining weed free condition through three hand weedings at 20, 40 and 60 days after sowing (DAS) resulted minimum number of weeds and drymatter of weeds thus significantly higher castor bean yield of 1025 kg/ha as compared to all other treatments. This treatment also recorded highest gross (₹ 15379/ha) and net returns (₹ 8853/ha) and B:C ratio (2.36) besides lowest amount weed drymatter (202 g/m^2). Next best treatment was intercropping of castor with groundnut (1:4) in terms of castor seed equivalent yield (701 kg/ha) and B:C ratio (1.3) and weed control efficiency (81.5%). The treatments *viz.*, unweeded check, application of pre-emergence herbicide *(Alachlor or Pendimethalin) alone or in combination with one hand weeding at 40 DAS were not prove effective as* returns were negative.

Keywords: *Alachlor, castor, intercultivation, pendimethalin, rainfed condition, weed free condition*

Introduction

Castor (*Ricinus communis* L.) is one of the most important traditional crops grown in Mahaboobnagar, Nalgonda, Ranga Reddy, Prakasam, Kurnool, Anantapur and Kadapa districts of Andhra Pradesh besides cotton, sorghum, maize, groundnut sunflower, pulses and millets under rainfed conditions. However, 80% of the castor acreage is concentrated mainly in southern Telangana zone covering Mahaboobnagar and Nalgonda districts. It is a livelihood crop of resource poor farmers in these districts. Castor is preferred crop owing to its excellent rejuvenating capacity and genetic potential to give some yield even under adverse situations. Weed menace has been identified as the most important critical component for realising remunerative yields in castor as per the results of experiments conducted in 11 AICRP on Castor centres all over India. Non-adoption of weeding has reduced the seed yield by 1558 kg/ha as compared to adoption of full package of agronomic practices at Mandore, Rajasthan (Singh, 2008) and 1062 kg/ha at S.K. Nagar, Gujarat. Weed menace is high in castor because of its long duration, slow initial growth up to 45 DAS and adoption of wide spacing (90 cm x 60-90 cm) which facilitates easy availability of light and other natural resources to the weeds. Moreover, competition for moisture will be high between crop plants and weeds under rainfed conditions. Further, lack of labour force and mechanization in dryland areas are the major hurdles for achieving timely weed control. Hence, more efforts are needed to keep the weeds under check under rainfed conditions due to unexpected and incessant rains during which mechanical or chemical control methods will be ineffective. This experiment was planned based on the concept of integrated weed management involving combination of physical, mechanical and chemical methods to find out suitable, feasible and economical weed control method in castor.

Materials and methods

A field experiment was conducted during the rainy season of 2005 at Regional Agricultural Research Station (ANGRAU), Palem, Mahaboobnagar dist., Andhra Pradesh study the effect of various weed management practices on growth and yield of castor. The soil of experimental site was slightly acidic (pH: 6.8) and low in available N (350 kg/ha), high in available phosphorus (35.0 kg P_2O_5/ha) and potash(310 kg K_2O/ha). The site of experiment was ploughed twice with cultivator and levelled by using tractor drawn blade. Castor variety Haritha, released from RARS, Palem was used in the present study. The experiment was laid out in a randomised block design with 7 treatments (T_1: Alachlor @ 1.5 kg a.i./ha; T_2: Alachlor @ 1.5 kg a.i./ha + one hand weeding at 40 DAS; T_3: Pendimethalin @ 1.0 kg a.i./ha; T_4: Pendimethalin @ 1.0 kg a.i./ha + One hand weeding at 40 DAS; T_5: Castor + groundnut 1:4; T_6: Weed free condition with 3 weedings at 20, 40, 60 DAS; T_7:

Unweeded control and three replications. The size of the gross plot was 5.4 x.6.0 m^2 (6 rows and 10 plants) and net plot was 3.6 x 4.8 m^2 (4 rows x 8 plants). Sowing was done on 12 July, 2005.

The data on weed count and dry matter was recorded at 120 DAS coinciding with the first picking. The plant population, plant height, yield attributing characters were recorded at the time of harvesting primary spike at 120 DAS. Seed yield from all the three pickings was pooled for arriving at final seed yield. Weed control efficiency was calculated by using the following formula (Gupta, 1998).

Weed control efficiency: (WC-Wt/WC) x100

Where WC : Average weed weight per unit area in the unweeded control plot

Wt : Average weed dry weight per unit area in plot under treatment

Results and discussion

The experimental results revealed that maintaining weed free condition through three hand weedings each at 20, 40 and 60 DAS resulted in significantly higher castor bean yield of 1025 kg/ha. This can be attributed to weed free environment as evident through lowest amount of drymatter (202 g/m^2 only) which helped in maintaining significantly higher plant population (17960/ha). It might have facilitated utilization of water, nutrients, land and light by the crop plants efficiently. This in turn resulted in taller plants, more number of effective spikes, longer spikes (total and effective spike length) (Table 1). This result is in conformity with that of results obtained during 2008-09 and 2009-10 at Mandore, Rajasthan (DOR. 2008-09 and 2009-10). This treatment also showed superiority in terms of gross (₹ 15379/ha) and net returns (₹ 8853/ha) and B:C ratio (2.36) over other treatments under test. Next best treatment was intercropping of castor with groundnut (1:4) in terms of castor seed equivalent yield (701 kg/ha) and B:C ratio (1.3). But it showed superiority in weed control efficiency (81.5%) over other treatments. The treatment unweeded check had significantly higher weed dry matter (2194 g/m^2) and lower plant stand (5200/ha) thus it was significantly inferior to all other treatments in seed yield (79.8 kg/ha) and net returns (₹ 4852/ha) and B:C ratio (0.19). The other treatments *viz.*, application of pre-emergence herbicide (Alachlor or Pendimethalin) alone or in combination with one hand weeding at 40 DAS were not proved effective in arresting weed growth as evident through highest amount of weed dry matter (510 to 953 g/m^2), significantly less seed yield (165 to 256 kg/ha) and negative net returns (₹ -3900 to -4272/ha) and B:C ratio less than one (0.37 to 0.49). From the foregoing discussion it can be concluded that maintaining weed free condition up to 60 DAS is very important in reaping remunerative seed yield of castor under rainfed conditions.

Table 1 Growth parameters, yield attributes, yield and economic returns as influenced by weed management in castor (rainy season, 2005)

Treatment	Plant population at first picking ('000)	Plant height up to primary receme (cm)	Effective spikes/ plant	Total spike length (cm)	Effective spike length (cm)	Seed yield (kg/ha)	Weed drymatter (g/m^2)	WCE** (%)	Gross Returns (Rs/ha)	Net Returns (Rs/ha)	B : C ratio
Alachlor @ 1.5 kg a.i. /ha	1.12	22.1	2.1	12.2	9 2	165	953	37.26	2478	-4272	0.37
Alachlor @ 1.5 kg a.i./ha + one hand weeding at 40 DAS	2.56	23.5	2.2	12.9	10.2	200	510	55.02	3005	-4020	0 43
Pendimethalin @ 1.0 kg a.i./ha	1.47	28.1	2.3	13.0	9.8	197	751	23.83	2950	-4400	0.40
Pendimethalin @ 1.0 kg a.i./ha+one hand weeding at 40 DAS	2.63	35.7	2.5	14.2	10.7	256	590	40.81	3849	-3901	0.49
Inter cropping castor+ groundnut (1.4)	11.25	46.9	3.1	24.6	19.7	701*	230	81.54	10518	2493	1.31
Weed free condition (3 weedings at 20.40, 60 DAS	17.96	52.6	3.2	32.7	24.7	1025	202	78.68	15378	8853	2.35
Unweeded check	0.52	12.8	1.65	8.21	6.36	79 8	2194	0	1197	-4852	0.19
SEm±	0.3	0.9	0.2	0.7	0.6	27.0					
CD (P=0.05)	1.0	2.7	0.7	2.2	1.7	70.6					

* Castor equivalent yield; **Weed control efficiency; Price of castor seed: Rs. 1500/qtl (during 2006)

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Effect of sowing date and irrigation scheduling on yield and economics of winter castor in southern Telangana zone of Andhra Pradesh

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Abstract

A field experiment was conducted during the winter season of 2007 in the experimental farm of Regional Agricultural Research Station (ANGRAU), Palem, Mahaboobnagar dist., Andhra Pradesh to study the effect of sowing date and irrigation scheduling on seed yield and economics of winter castor. The experimental results revealed that sowing on 1st October resulted in significantly higher seed yield of castor (23.0 q/ha). With delay in sowing from October 1 to October 15, November 1 and November 15, seed yield of castor declined by 21.3, 25.2 and 30.4%, respectively. Among the irrigation levels, scheduling of irrigation at 50 mm cumulative pan evaporation (CPE) gave significantly higher bean yield of castor (19.6 q/ha) which is 8.0% more than that of 75 and 100 mm CPE. Sowing on 1st October gave higher water use efficiency (4.06 kg/ha/mm) and higher B:C ratio (4.6). Though, scheduling of irrigation at 50 mm was found to be superior in terms of B:C ratio (3.8), water use efficiency was higher with 100 mm CPE (4.36 kg/ha/mm).

Keywords: Winter castor, sowing date and irrigation scheduling

Introduction

Castor (*Ricinus communis* L.) is an important industrial and non-edible oilseed crop of arid and semi-arid regions of the world. India is the world leader having maximum area (59%), production (64%) and productivity (1339 kg/ha) and meets 90% of the world's requirement of castor oil, earning about Rs. 2000 crores of foreign exchange annually (Pathak, 2009). In India, it is mainly grown in Gujarat, Andhra Pradesh, Rajasthan, Chattisgarh, Karnataka, Orissa and Tamil Nadu. Though Andhra Pradesh stands second in area (1.99 lakh ha) and third in production (1.29 lakh t), the productivity levels are very low (648 kg/ha) as compared to Haryana (2471 kg/ha), Gujarat (1978 kg/ha), Rajasthan (1458 kg/ha), all India average (1339 kg/ha) and Assam and Bihar (1000 kg/ha).

In Andhra Pradesh, the castor crop is mainly grown in Mahaboobnagar, Nalgonda, Ranga Reddy, Prakasam, Kurnool, Anantapur and Kadapa districts. Mahaboobnagar and Nalgonda located in southern Telangana zone of Andhra Pradesh account for 80% of castor area in A.P. It is a livelihood crop of resource poor farmers in these districts. Castor is preferred crop owing to its excellent rejuvenating capacity and genetic potential to give some yield even under adverse situations.

Castor is generally grown with local/improved varieties on red *chalka*, sandy to loamy sand soils in Andhra Pradesh in general and Mahaboobnagar district in particular. These sub-marginal and marginal lands are characterized by shallow depth, low water holding capacity and poor soil fertility. Crop during rainy season is often caught by vagaries of monsoon like delay in onset of monsoon and prolonged dry spell or even failure of monsoon. Sometimes, the crop is also severely affected by *Botrytis* grey rot when it is at flowering/capsule development stage. Consequently, the realized productivity is only 25 to 30% of actual potential yield. Thus, castor productivity during rainy season in traditional tracts is very low i.e., 300-400 kg/ha, which is a great cause of concern. Moreover, the area under castor in Mahaboobnagar district during these years is going down due to due to drought, fear of *Botrytis* and up coming of competitive crops like Bt cotton and maize during rainy season. But, considering wide array of uses of by-products of castor, enhancing productivity of castor is imminent. Growing of castor during winter season under irrigated conditions is a new dimension. Moreover winter castor is free from *Botrytis* menace and can be grown with less water and risk. This experiment was conducted as the information on optimum date of sowing, irrigation interval and amount of irrigation water required is scanty.

Materials and methods

A field experiment was executed during winter 2007 at Regional Agricultural Research Station (ANGRAU), Palem, Mahaboobnagar dist., Andhra Pradesh to study the effect of sowing date and irrigation scheduling on seed yield and economics of winter castor. The experimental site had 6.5 pH, 376.2 kg N/ha, 42.1 kg P_2O_5/ha and 330.6 kg K_2O/ha. The site of experiment was ploughed once with mould board plough, twice with cultivator and leveled by using tractor drawn blade. For this experimental purpose, castor hybrid DCH-177 was used. The experiment was laid out in a split plot design with three main plots [irrigation levels - 50mm, 75 mm and 100 mm cumulative pan evaporation (CPE)] and 4 sub lots (dates of sowing - October 1, October 15, November 1 and November 15) replicated thrice. The size of the gross plot was 5.4 x 7.2 m^2 (6 rows and 12 plants) and net plot was 3.6 x 6.0 m^2 (4 rows x 10 plants). Care was taken to avoid water flow from one treatment to another by giving irrigation in the middle channel leaving buffer channels on both the sides unirrigated. The sowing was done as per the treatment on 1st October, 15th October, 1st November and 15th November. The details of evaporation and rainfall recorded from meteorological station of RARS, Palem was considered for arriving at cumulative pan evaporation. The irrigation treatments were imposed as and when cumulative evaporation reached 50mm, 75mm or 100 mm CPE. The crop received recommended dose of fertilizer 80:40:30 kg N, P_2O_5 and K_2O/ha with half the dose of N and full dose of phosphorus and potash as basal, while the remaining half the dose of nitrogen was applied in three equal split doses at 30, 60 and 90 DAS. The plant population, plant height, yield attributing characters were recorded at the time of harvesting primary spike at 120 DAS. The harvesting of spikes was done as and when they matured. A total of three pickings were done. Seed yield from all the three pickings was pooled for arriving at final seed yield. Water use efficiency was calculated by dividing the seed yield of castor by total water use.

Results and discussion

A perusal of data presented in table 1 indicated that sowing on 1st October resulted in significantly higher seed yield of castor (23.0 q/ha). This is mainly due to significantly more plant population and longer spikes. With delay in sowing from October 1 to October 15, November 1 and November 15, seed yield of castor declined by 21.3, 25.2 and 30.4%, respectively. Castor crop sown at later dates was stunted in growth thus produced shorter spikes. Sowing on 1st October gave higher water use efficiency (4.06 kg/ha/mm) and higher B:C ratio (4.6). Nagabhushanam and Raghavaiah (2005) also obtained significantly higher seed yield of castor when sown on October 15 than that of November 1 and November 15 at Hyderabad.

Among the irrigation levels, scheduling of irrigation at 50 mm CPE (wet regime) gave significantly higher bean yield of castor (19.6 q/ha) which is 8% more than that of 75 and 100 mm CPE. This might be because of availability of sufficient moisture and efficient nutrient utilization. Though, scheduling of irrigation at 50 mm was found to be superior in terms of B:C ratio (3.8), water use efficiency was higher with 100 mm CPE (4.36 kg/ha/mm). According to Pratap Kumar Reddy *et al.* (2006) irrigation has to be scheduled at 55 mm to 80 mm CPE for winter castor. Nagabhushanam and Raghavaiah (2005) also concluded that castor has to be irrigated at 0.8 IW/CPE ratio (wet regime). While Sesha Saila Sree and Bhaskar Reddy (2005) recommended irrigation scheduling at 80 mm CPE for summer castor under rice fallows as it gave significantly higher seed yield of castor.

Thus, it can be concluded that sowing on 1st October and irrigation scheduling at 50 mm CPE has to be done for realizing higher seed yield and net returns from winter castor in southern Telangana zone of Andhra Pradesh.

Table 1 Growth parameters, yield attributes, seed yield and economic returns of winter castor as influenced by sowing date and irrigation (winter, 2007)

Treatment	Plant population ('000/ha)	Plant height (cm)	No. of effective spikes/plant	Total spike length (cm)	Seed yield (q/ha)	WUE (kg/ha/mm)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Irrigation levels (mm CPE)									
50	15.8	97.9	4.7	51.4	19.6	2.75	49000	36155	3.8
75	15.6	94.9	5.4	49.3	18.1	3.53	45250	33005	3.7
100	15.8	95.3	4.6	47.9	18.0	4.36	45000	32955	3.7
SEm±	0.6	9.77	0.7	1.51	0.15				
CD (P=0.05)	NS	NS	NS	NS	0.47				
Sowing date									
Oct 1	16.0	111.7	5.8	52.4	23.0	4.06	57500	45005	4.6
Oct 15	14.5	80.2	6.2	46.3	18.1	3.19	45250	32555	3.6
Nov 1	15.0	86.2	4.0	49.6	17.2	3.22	43000	30905	3.6
Nov 15	17.3	105.9	3.5	49.4	16.0	3.10	40000	27762	3.3
SEm±	0.7	6.4	0.8	2.7	0.79				
CD (P=0.05)	2.1	18.9	2.4	NS	2.40				

* Price of castor seed: Rs. 2500/qtl

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Effect of integrated nutrient management practices on growth and yield of castor, *Ricinus communis* L. under irrigated conditions

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Abstract

A field experiment was conducted during the rainy seasons of 2004, 2005 and 2006 Gujarat to investigate the effect of integrated nutrient management practices on growth, yield attributes, seed yield and economics of irrigated castor (*Ricinus communis* L.). The treatments consisted of different combinations of organic farm yard manure (FYM), castor cake and green manuring of sunnhemp) and inorganic (100, 75, and 50 % of recommended dose of fertilizer (RDF) which were tested in randomised block design with three replications. Pooled results of three years revealed that the application of 100 % recommended dose of fertilizer + *in situ* green manuring of sunnhemp recorded significantly higher plant height (166.3 cm), number of effective branches/plant (9.32), length of primary spike (36.4 cm) and number of spikes/plant (10.6) as compared to 75 % RDF. Significantly the highest seed yield (3517 kg/ha) was obtained with 100 % RDF + *in situ* green manuring of sunnhemp which was higher by 41.9, 22.8 and 12.5% over 50, 75 and 100% RDF without in situ green manuring, respectively. Application of 75 % RDF + 25 % N through FYM or castor cake was also proved effective for higher productivity of castor.

Keywords: Castor, integrated nutrient management, castor cake, green manuring, seed yield

Introduction

Castor is one of the important non - edible oilseed and industrial crops of India which fetches sizeable amount of foreign exchange to the country. India's share in world's area and production of castor is 68 and 76 %, respectively. India occupies a premier position in the area, where 8 lakh ha is under castor cultivation with production and productivity of 11.2 lakh tonnes and 1392 kg/ha, respectively during 2008-09 (Anonymous, 2010). In India, Gujarat is leading state in castor production, which contributes nearly 80% of the production. Imbalanced use of inorganic sources of nutrients has detrimental effect on soil health. Therefore, partial fulfillment of the nutrient requirement through organic sources has become necessary (Singh *et al.*, 2006). Integration of organic and inorganic has been found to be quite promising not only in maintaining higher productivity but also in providing greater stability in crop production by improving soil physical conditions *viz.*, reducing soil crusting, increasing water holding capacity, hydraulic conductivity and infiltration rate. Popularising the use of organics to reduce the dependence on chemical fertilizers and to contribute to pollution free environment is imperative. Farm yard manure (FYM) and castor cake have been advocated as a good organic manure and easily available source for use in integrated nutrient management (INM) programme in field crops. Therefore, there is an urgent need to develop a system using organic and inorganic on complementary basis, which may enhance the efficiency and simultaneously reduce the requirement of inorganic source of nutrients. Integration of organic, inorganic, crop residue and bio fertilizers may improve the soil productivity (Kumar *et al.*, 2001 and Patel *et al.*, 2007). Information on effect of organic sources like FYM, castor cake and *in situ* green manuring in combinations with chemical fertilizers on castor productivity is limited. Hence, the present study was under taken.

Materials and methods

A field experiment was conducted for consecutive three years during the rainy season of 2004-05, 2005-06 and 2006-07 at Regional Research Station, Anand Agricultural University, Anand. The soil of the experimental field was loamy sand, low in organic carbon and nitrogen, medium in available phosphorus and high in available potassium and had pH 7.2, electrical conductivity 0.2 dS/m with field capacity 17.2% and permanent wilting point 8.9%. The total rainfall during crop period was 1112, 1693 and 1361 mm during 2004-05, 2005-06 and 2006-07, respectively. The experiment was conducted in randomised block design with 12 treatments and three replications. The treatments comprised of different combinations of organic (FYM, castor cake and green manuring of sunnhemp) and inorganic (100, 75 and 50 % of recommended dose of fertilizer). The treatment details are given in table 1. In the treatment of *in situ* green manuring, sunnhemp was sown during 3rd week of June and was incorporated in to soil 40-45 days after sowing. Castor cake (4.7% N) and FYM (0.48% N) were applied in furrows as per treatments. The GCH-5 castor hybrid was sown on 30 August, 2004; 28 August, 2005 and 4 September, 2006 and was harvested up to 10th April in all the three years. The crop was sown at a spacing of 120 cm x 60 cm. The recommended dose of fertilizer (RDF) was 75:50:0 kg NPK/ha. Entire dose of phosphorus and half dose of nitrogen as per treatment were applied as basal and the remaining nitrogen was applied at 35 days after sowing. Seven irrigations were given to the crop at 20-25 days interval after cessation of monsoon. The other package of practices of castor crop was fallowed as per recommendation.

Results and discussion

Growth and yield components: Growth and yield components of castor *viz.*, plant height, effective branches/plant, length of primary spike and spikes/plant were significantly influenced due to INM practices (Table 1). The application of inorganic fertilizer in combination with organic sources *viz.*, FYM or castor cake or *in situ* green manuring of sunnhemp was found promising and increased growth and yield components over 50% RDF applied through inorganic. Application of 100% RDF + *in situ* green manuring of sunnhemp (T_{10}) recorded significantly higher plant height (166.3cm), effective branches/plant (9.32), length of primary spike (36.4cm) and number of spikes/plant (10.6) which was comparable with 75% RDF + 25% N through FYM but significantly superior to the plots fertilized with inorganic fertilizer with 50 and 75% RDF. The oil content and 100 seed weight of castor were not affected significantly due to organic and inorganic sources of nutrients. These findings are in agreement with Patel *et al.* (2007) and Anonymous (2008). The increase in growth and yield components might be due to improvement in physico-chemical properties of the soil and more availability of nutrients and moisture to the crop (Patra *et al.*, 2000, Kumar *et al.*, 2001 and Ramesh *et al.*, 2009).

Seed yield: Higher seed yield (3772 and 3763 kg/ha) was obtained during 2005-06 and 2006-07, respectively with 100% RDF + *in situ* green manuring of sunnhemp was significantly higher as compared to rest of treatments (Table 2). However, this treatment was on par with 75% RDF + 25% N through castor cake during 2005-06 and 2006-07 and with 75% RDF + 25% N through FYM during 2005-06. The pooled analysis indicated significantly the highest seed yield (3517 kg/ha) with *in situ* green manuring of sunnhemp + 100% RDF and remained comparable with 75% RDF + 25% N through FYM. *In situ* green manuring of sunnhemp + 100% RDF proved beneficial and it increased the seed yield to the extent of 41.9, 22.8 and 12.5% over 50, 75 and 100% RDF without *in situ* green manuring. Being a long duration crop, castor fully utilized the readily available nutrient from green manure and in turn produced higher seed yield. Substitution of 25% N through organics like FYM or castor cake also proved better as the seed yield was improved with 75% RDF + 25% N through FYM (3317 kg/ha) and 75% RDF + 25% N through castor cake (3154 kg/ha) were found significantly superior to 75% RDF and remained comparable with seed yield obtained with 100% RDF. These results are corroborating with findings of Pang and Letey, (2000); Reddy *et al.* (2006); Singh *et al.* (2006); Patel *et al.* (2007) and Anonymous (2008).

Table 1 Growth and yield attributes of castor as influenced by integrated nutrient management practices (pooled data of 3 years)

Treatment	Plant height (cm)	Effective branches/plant	Primary spike length (cm)	Spikes/ plant	100 seed weight (g)	Oil content (%)
50 % RDF	137.7	6.3	32.0	7.8	30.49	49.5
75 % RDF	151.6	7.6	33.9	8.7	31.44	49.6
100 % RDF	159 9	8.9	35.4	9.6	31.67	49.5
75 % RDF + 25 % N through FYM	159.3	8.7	35.8	9.8	32.24	49.4
50 % RDF + 50 % N through FYM	152.6	7.7	34.2	8.8	31.61	49.4
25 % RDF + 75 % N through FYM	151 8	7.4	33.3	8.3	30.63	49.6
75 % RDF + 25 % N through castor cake	158.9	8.5	35.7	9.4	31.92	49.6
50 % RDF + 50 % N through castor cake	155.0	8.2	34.6	9.0	31.38	49.7
25 % RDF + 75 % N through castor cake	159.0	7.9	33.5	8.7	31.21	49.5
100 % RDF + *in situ* green manuring of sunnhemp	166.3	9.3	36.4	10.6	31.88	49.5
75 % RDF + *in situ* green manuring of sunnhemp	151.9	8.0	35.2	8.8	31.31	49.6
50 % RDF + *in situ* green manuring of sunnhemp	152.2	7.4	34.4	8.6	31.17	49.5
CD (P=0.05)	9.7	0.9	2.1	0.9	NS	NS

Organic source played a key role in enhancing efficient utilization of the native as well as applied nutrients through matching nutrient availability with crop requirement to exhibit crop's productive capacity. These organic sources also supply some micro nutrients and growth promoting substances, which might have helped in attaining higher branches/plant, length of primary spike and number of spikes/plant which in turn increased the seed yield (Patel *et al.*, 2007). Economic analysis of different INM practices (Table 2) showed that maximum net return of Rs. 38945/ha was obtained with the application of 100% RDF + *in situ* green manuring of sunnhemp followed by 75% RDF + 25% N through FYM (Rs. 37691/ ha). Owing to higher cost of this treatment, BCR was low (3.82) compared to BCR recorded with 100% RDF (4.22).

Thus, the application of 100% RDF + *in situ* green manuring of sunnhemp enhanced the productivity of castor grown on loamy sand soil of Gujarat. Application of 75% RDF + 25% N through FYM or castor cake was also found effective for realising higher productivity and economics returns.

Table 2 Seed yield and economics of castor as influenced by integrated nutrient management practices

Treatment	Seed yield (kg/ha)				Net return	BCR
	2004-05	2005-06	2006-07	Pooled	(Rs / ha)	
50 % RDF	2399	2458	2578	2478	26965	3.64
75 % RDF	2774	3039	2779	2864	33052	4.10
100 % RDF	2959	3143	3272	3125	35765	4.22
75 % RDF + 25 % N through FYM	3026	3650	3275	3317	37691	4.12
50 % RDF + 50 % N through FYM	2655	3097	3059	2937	31037	3.38
25 % RDF + 75 % N through FYM	2545	2697	2707	2650	25778	2.84
75 % RDF + 25 % N through castor cake	2629	3530	3304	3154	34027	3.56
50 % RDF + 50 % N through castor cake	2363	3034	2973	2790	26395	2.71
25 % RDF + 75 % N through castor cake	2750	2778	2966	2831	24837	2.41
100 % RDF + *in situ* green manuring of sunnhemp	3016	3772	3763	3517	38945	3.82
75 % RDF + *in situ* green manuring of sunnhemp	2434	3169	3206	2936	30682	3.30
50 % RDF + *in situ* green manuring of sunnhemp	2312	2716	2932	2653	26890	3.08
CD (P = 0.05)	NS	388	470	282		

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Yield advantages in castor through adoption of recommended package of practices on farmers' field

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Abstract

Castor (*Ricinus communis* L) is most important oil seed crop in Gujarat. One of the major constraints of its low productivity is non-adoption of improved technologies, non availability of wilt resistant variety/hybrids and poor irrigation management practices. Intercropping of castor with other cropping is also helps in increasing the income of the farmers. The results of field demonstration conducted on farmers field revealed that wilt resistant castor hybrid GCH 7 produced 23.2% higher seed yield over local hybrids/varieties. Similarly, application of sulphur @ 40

kg/ha recorded 21.1% yield gain over control. On an average, 10.8 and 76.4% more income generated with adoption of intercropping of castor with urdbean and cotton, respectively. Adoption of drip irrigation system recorded 29.2% higher seed yield of castor as compared to traditional (flood irrigation) system.

Keywords: Castor, intercropping, drip, demonstration

Introduction

India is the world leader in castor production and export of castor oil and contributes about 55% of world castor area and 70% of world castor production. In the country, Gujarat state holds the first rank in area 3.5 lakh ha (47%), production (71%) and productivity (1838kg/ha, 2007-08). The state made significant contribution in the field of castor production through development of hybrids, generating production and plant protection technology. The efforts made so far were mostly concentrated to increase the productivity of castor. However, the increased productivity is quite less than the genetic potential of hybrids released. Farmers are generally getting lower seed yield and low price for the produce for want of quality hybrid seed of recently released hybrids, partial/ non adoption of improved production/protection technology and lack of easy access to information on technology at farm level. The productivity of castor can be increased by increasing availability of latest castor hybrid and dissemination of improved technology. Sulphur is an essential element for oil synthesis and its response on different field crops is well documented. Seed yield and oil content increase with sulphur application. Owing to use of high analysis fertilizers, cultivation of high yielding varieties, intensive cropping systems and non-availability of organic manures, sulphur deficiency is recognized in most of the agricultural soils. Response of sulphur on growth and yield of different crops is reported by various scientists. Therefore, it is an urgent need to demonstrate the response of sulphur on oilseeds especially castor on farmer's fields. Water is one of the most critical inputs in agriculture which consumes more than 80 % of the water resources of the country. Availability of adequate quantity of water is, therefore, a key factor for enhancing agricultural productivity. Micro-irrigation system which is the most efficient method of irrigation has become popular in India. Intercropping of castor with other crops is an easy and popular practice to increases the total productivity of a unit area.

Materials and methods

Field demonstrations were conducted on farmer's fields of six adopted villages during rainy season of 2009 on various aspects of production technologies including recently released wilt resistant castor hybrid GCH 7. The soils of the demonstration sites were light to medium fertility status. All the demonstrations, expect Garamadi village conducted under irrigated situation. The crop was treated as per aspects of demonstration conducted. All other operations were done as per package of practices recommended for castor. On the basis of information collected through survey for different aspects *viz.*, use of wilt resistant hybrid GCH 7, application of sulphur @ 40 kg/ha, use of drip irrigation system and castor intercropped with cotton were selected. The yield level of selected villages *viz.* Gangudara, Chodungari, Kamali, Matpur, and Garamadi (rainfed) was 19-21, 23-25, 31-33, 33-34 and 6-8 q/ha, respectively. Total 465 demonstrations were conducted in selected villages on these aspects.. Considering the available resources a target yield level for different villages (Table 1) was fixed.

Results and discussion

The results (Table 1) indicated that the range of actual production of castor seed in different selected villages was 11.54 to 49.38 q/ha. The result further revealed that about 19.9 to 64.9% seed yield of castor found to be increased with the adoption of recommended practices over traditional castor cultivation. On an average, the magnitude of increase in yield over present level and targeted yield was 34.1 and 11.7%, respectively.

Response of GCH-7 hybrid: About 148 farmers were selected to demonstrate the response of newly released wilt resistant and high yielding hybrid GCH 7 in five selected villages *viz.*, Kamali, Matura, Garamadi, Gangudra and Chodungari. The results (Table 2) indicated that the magnitude of increase in seed yield under GCH 7 was varied from 17.5 to 33.9% in different villages over local hybrids/varieties. On an average GCH-7 produced 23.2% higher seed yield and 31% higher net returns over local one.

Response of sulphur application: About 281 farmers were selected to demonstrate the response of sulphur on castor in five selected villages *viz.*, Kamali, Matura, Garamadi, Gangudra and Chodungari. The results indicated that the magnitude of increase in seed yield with sulphur application (40 kg/ha as basal) was varied from 16.2 to 27.4% with sulpuur application over control. On an average, application of sulphur recorded 21.1% higher seed yield and 27.9% higher net returns over control (Table 3). Similar results were reported by Patel *et al.* (1994).

Effect of drip irrigation system: Ratanpur village was selected to demonstrate drip irrigation method in castor crop. The results of 10 demonstrations indicated that application of water through drip system recorded 29.2% higher yield over flood irrigation system (Table 4).

Table 1 Average present yield, expected yield and actual yield of five selected villages

Village	Present yield status (q/ha)	Targeted yield (q/ha)	Actual yield (q/ha)	Actual increase over present status (%)
Gangudara	19-21	23-25	28.18	40.9
Chodungari	23-25	28-30	28.78	19.9
Kamali	31-33	35-37	40.73	27.3
Matpur	33-34	38-40	42.50	23.9
Garamadi	6-8	10-12	11.54	64.9
Ratanpur	32-35	40-42	49.38	47.4
Mean	25	30 (20 %)	33.52 (11.7 %)	34.1

Effect of intercropping system: Total 10 demonstrations on intercropping system were conducted in Danta and Kamali villages. Results clearly indicated that intercropping of castor with pulse and cotton found beneficial in generating additional income. Results indicated that intercropping of castor with urdbean and cotton registered 10.68 and 76.1% higher net income as compared to sole castor and cotton, respectively. The magnitude of increase in castor equivalent yield with urdbean and cotton intercropping system were 13.3 and 62.9% over sole castor, respectively. These results are in conformity with the finding of Patel *et al.* (2009) and Singh (2009).

Conclusion: The results indicated that GCH-7 hybrid found higher productivity and wilt resistant. Application of sulphur in castor found beneficial. Drip irrigation system recorded higher profitability in castor and intercropping of castor with cotton found profitable.

Table 2 Comparison of response of GCH-7 hybrid with local hybrids/varieties of castor

Name of village	Yield (kg/ha)		Total income (Rs/ha)		Cost of cultivation (Rs/ha)	Net income (Rs/ha)		% higher over local yield
	GCH 7	Local	GCH 7	Local		GCH 7	Local	
Gangudara	2212(24)	1825 (25)	61936	51100	21733	40203	29367	21.2
Chodungari	2878 (39)	2150 (25)	80597	60200	26031	54566	34169	33.9
Matpur	3656 (18)	3050(25)	102368	93800	31847	70521	61720	19.9
Kamali	3506(25)	2985 (25)	98168	83580	30086	68082	53493	17.5
Garamadi	926 (42)	750 (25)	25928	21000	11840	14088	9160	23.5
	2636	2152				49486	37782 (31.0)	(23.2)

Table 3 Effect of sulphur on castor seed yield and economics

Name of village	Yield (kg/ha)		Total income (Rs/ha)		Cost of cultivation (Rs/ha)		Net income (Rs/ha)		% higher yield over without S
	With S	Without S	With S	Without S	With S	Without S	With S	Without S	
Gangudara	2818 (76)	2212 (24)	78904	61936	22380	21733	56524	40203	27.4
Matpur	4250 (73)	3656 (18)	119000	102368	32140	31847	86860	70521	16.3
Kamali	4073 (100)	3506 (25)	114044	98168	30373	30086	83671	68082	16.2
Garamadi	1154 (32)	926 (42)	32312	25928	12620	11840	19692	14088	24.6
Mean	3074	2575					61687	48224(27.9 %)	21.1

Figures in parentheses are number of demonstrations

Table 4 Effect of drip irrigation system on seed yield and economics of castor

Name of village	Yield (kg/ha)		Total income (Rs/ha)		Cost of cultivation (Rs/ha)		Net income (Rs/ha)		% higher yield over flood irrigation
	Drip	Flood	Drip	Flood	Drip	Flood	Drip	Flood	
Ratanpur	4938 (10)	3823 (10)	138264	107044	31289	27200	106975	79844	29.2

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Identification of castor genotypes for water use efficiency (WUE) and root traits

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Abstract

Sixty four genotypes were sown in two specially constructed structures at DOR to identify castor germplasm and breeding lines for better water use efficiency (WUE) and root traits. In each structure, 32 lines were sown in two replications with four plants per replication. Observations on various growth parameters, WUE traits, root characters and total dry matter (TDM) were recorded at the time of harvest (90 days after sowing). Among different root characters, root volume and root dry weight showed strong positive correlation (r > 0.80) compared to root length (r = 0.32) with TDM. Leaf area index (LAI) and stem girth also showed strong positive correlation of >0.80 with TDM. Among the 64 lines screened, thirteen lines showed root length >230 cm, root volume of >250 ml, root dry weight of >40g, LAI >3.0 and TDM >350g/plant. These lines include RG 1450, RG 1611, RG 1661, RG 1826, RG 2122, RG 2149, RG 2714, RG 2797, RG 2826, RG 2850, RG 3063, GCH 5 and 48-1.

Keywords: Water-use efficiency, root characters, TDM, castor

Introduction

Efficient use of stored water, increased biomass productivity per unit water use and highest conversion of vegetative biomass to economic yield are the ultimate goals of any drought management research. Among the many traits associated with drought tolerance, root characters and water use efficiency (WUE) are considered to be most relevant. Good root system is essential for crop plants to grow under moisture deficit conditions. Specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR), carbon isotope discrimination (^{13}C) are the traits used as surrogates for measuring WUE. Improvement of these traits has been shown to increase the productivity in several species (Sheshashayee *et al.*, 2003).

As castor is generally grown in rainfed conditions, root growth is important to extract available soil moisture from deeper layers. Quantification of root growth helps in selecting genotypes with better root characters and correlating growth with WUE traits helps in identifying genotypes with high WUE. Genotypes with good root growth and WUE traits performed better and had positive effect on seed yield through improved transpiration even under moisture stress in crops like groundnut (Wright *et al.*, 1991), soybean (Cortes and Sinclair, 1986). Therefore, an experiment was conducted during rainy season of 2007 to screen castor genotypes in root structures for root and WUE traits.

Materials and methods

Two structures of 30m length, 1.5m height and 2.4m width on either side of central 30cm permanent wall were constructed at Narkhoda farm of DOR for screening castor germplasm and breeding lines for WUE and root traits. Sixty four castor genotypes which include 56 germplasm lines and 8 AICRP entries were sown in 2 structures with 32 lines per structure during July and August 2007. Four plants were sown per replication with spacing of 90cm x 60cm with recommended dose of fertilizers. Plants were grown for 90 days.

Observations on growth parameters *viz.*, plant height, number of branches, leaf number, leaf area, stem girth, WUE traits like SCMR, SLA were recorded. Root structures were dismantled and plants along with roots were separated by using water jet and root characters i.e., root length, fresh weight, dry weight, root volume and TDM were recorded. Powdered leaf samples were sent to National facility of Isotope Ratio Mass Spectrometer (IRMS) at UAS, Bangalore for measuring ^{13}C.

Results and *discussion*

The data on different growth characters was recorded at 90 DAS. Mean and range for these growth characters are presented in table 1. There is variability in genotypes for plant height, leaf number, branch production, stem girth, TDM and root growth, etc. Root volume, root dry weight, LAI and stem girth showed strong positive correlation (>0.80) with TDM (Table 2). Root length did not show strong correlation with TDM as this experiment was conducted under sufficient moisture conditions. Root length is important to extract water from deeper soil layers when the crop experiences stress. Banda Mambani and Lal (1983) also reported variation in depth of root penetration for the different moisture regimes and varieties investigated in rice.

Specific leaf area is used as an alternate method for estimation of genetic variability for transpiration efficiency (TE) or WUE (Wright *et al.*, 1988). Similarly SPAD reading can also provide a good estimate of leaf chlorophyll content and hence specific leaf nitrogen (SLN). The relation between SCMR and TE was established by Sheshshayee *et al.*, (2001) in groundnut. Relationship between carbon isotope discrimination (CID) and WUE is studied by Farquhar and Richards (1984). Genotypes with high SCMR, low SLA, low ^{13}C and high ^{18}O are considered as best lines for WUE. SCMR and SLA did not show good correlation with TDM in castor.

Table 1 Shoot and root characters of castor genotypes

Character	Range (Mean)
Plant height (cm)	30 – 197 (96)
Leaf number	10 - 43 (25)
No. of Secondary branches	0 – 4 (3)
No. of Tertiary branches	0 – 5 (2)
Stem girth (cm)	6.3 – 11.3 (9.0)
SCMR	39.2 -54.2 (47.6)
SLA (dm^2/g)	1.2 – 3.3 (2.1)
Root length (cm)	141 – 293 (221)
Root volume (cm^3)	94 – 391 (205)
Root dry weight (g)	15 – 69 (35.7)
LAI	0.8 – 5.5 (2.7)
TDM (g)	100 – 638 (297)
Root density (W/V)*	0.59 – 1.00 (0.84)
Root /shoot ratio	4.2 – 24.6 (14.0)

* = NS; *Figures in parentheses are mean values*

Table 2 Correlation coefficients among different growth characters in castor

Character	Mean
Root length vs TDM	0.32
Root Volume vs TDM	0.83
Root dry weight vs TDM	0.85
LAI vs TDM	0.81
Plant height vs TDM	0.49
Leaf no. vs TDM	0.54
Stem girth vs TDM	0.81
SCMR vs TDM	0.15
SLA vs TDM	-0.08
SCMR vs SLA	-0.35

Table 3 Castor lines with better growth and root characters

Character	Mean	Germplasm lines
Root length	> 230 cm	RG 11, 337, 1441, 1450, 1611, 1661, 2122,2148, 2149, 2341, 2346, 2714, 2797, 2826, 2839, 3063, GCH-4, GCH-5, 48-1
Root volume	> 250 ml	RG 392, 1450, 1478, 1661, 1826, 2122, 2149, 2509, 2512, 2714, 2797, 2826, 2845, 2850, PSC-1111, JI-342, GCH-5, 48-1
Root dry weight	> 40 g/pl.	RG32,337,392, 1450, 1478, 1611, 1627, 1661, 1826, 2122, 2134, 2149, 2346, 2509, 2512, 2529, 2714, 2797, 2826, 2845, 2850, 3063, PSC-1111, JI-342, GCH-5, 48-1
LAI	> 3.0	RG 32, 392, 1450, 1478, 1482, 1627,1826, 2059, 2122, 2126, 2148, 2149, 2341, 2512, 2529, 2714, 2850,3063, GCH-4, PSC-1111, JI-342, GCH-5, DCH-177
TDM	> 350 g/pl.	RG 32, 392, 1450, 1478, 1482, 1611, 1826,2122, 2149, 2346, 2509, 2512, 2714, 2849, 3063, GCH-4, PSC-1111, JI-342, GCH-5, 48-1, DCH-177
SCMR	> 49	RG32,337, 1335, 1478, 1655, 1661, 2043, 2126, 2149, 2407, 2509, 2714, 2732,2826, 2839, 2845, 2850
SLA	< 2.0	RG337, 1419, 1493, 1588, 1655, 1661, 2043, 2092, 2122, 2126, 2132, 2134, 2341, 2346, 2407, 2509, 2826, 2839,
		2845, 2850, PSC-1111, SKI-294, GCH-5

Table 4 Growth characters of selected castor genotypes

Germplasm lines	Pl. ht (cm)	Leaf no.	Node no.	Stem girth (cm)	SCMR	SLA	LAI	^{13}C	TDM (g)	Root characters		
										Length (cm)	Volume (ml)	Dry weight (g)
RG 1450	168.5	27	20	10.0	46.9	2.57	4.9	-27.736	422	264	311	56
RG 1611	72.3	32	13	9.3	48.9	2.91	4.6	-28.824	395	232	247	44
RG 1661	32.8	32	8	10.0	49.5	1.79	2.9	-28.476	357	256	377	42
RG 1826	68.8	28	14	9.2	48.1	2.23	4.3	-28.453	427	219	269	52
RG 2122	80.5	33	14	9.9	48.2	1.92	4.1	-28.271	453	260	328	55
RG 2149	100.8	40	16	11.2	49.6	2.06	5.5	-28.866	638	232	391	69
RG 2714	87.0	41	19	10.0	51.1	1.61	4.0	-29.222	415	239	375	54
RG 2797	188.3	11	23	10.5	48.3	2.09	2.7	-28.254	312	258	263	48
RG 2826	132.3	37	19	9.9	53.3	1.99	2.6	-27.500	317	263	254	47
RG 2850	130.3	19	17	10.2	54.2	1.97	3.3	-27.291	379	214	263	50
RG 3063	196.8	32	23	10.8	48.7	2.13	4.9	-27.370	430	250	353	62
GCH-5	133.8	28	19	10.5	45.9	1.67	3.6	-28.866	438	258	336	55
48-1	107.0	30	17	10.7	44.2	2.16	2.5	-28.744	396	235	315	54
SEm ±	14.8	3.14	1.32	0.52	1.50	0.29	0.49		27.4	20.4	23.3	6.6
CD (P= 0.05)	42.4	9.0	3.8	1.5	4.3	0.37	1.41		78.9	24.4	66.9	16.2

Lines with better root, shoot characters are presented in table 3. Among the 64 lines screened, thirteen lines showed root length >230 cm, root volume of >250 ml, root dry weight of >40g, LAI >3.0 and TDM >350g/plant. These lines include RG 1450, RG 1611, RG 1661, RG 1826, RG 2122, RG 2149, RG 2714, RG 2797, RG 2826, RG 2850, RG 3063, GCH 5 and 48-1. None of the AICRP castor entries showed better shoot and root growth characters except for checks GCH-5 and 48-1. The growth and root characters of these thirteen lines are presented in table 4. Among all these lines RG 2714 showed highest leaf number, LAI, stem girth, root volume, root dry weight, SCMR and also low ^{13}C values. These lines are valuable as germplasm sources to transfer WUE and root traits to high yielding well-adapted cultivars.

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Scope of vesicular arbuscular mycorrhiza (VAM) in castor, *Ricinus communis* L.

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Abstract

Castor is grown in semi-arid tropics mainly in marginal as well as in fertile soils. Though this crop has high demand for nutrients it is starved with phosphorus (P) due to non-application of P fertilizers or due to its quick fixation. One area to work eco-friendly with soil environment is by improving the phosphorus availability of the fixed forms in soils through probing the association of the Vesicular Arbuscular Mycorrhiza (VAM) fungi with castor. It was found that there exists the association between VAM and castor crop. It was noted that *Glomus fasciculatum*, *G. constrictum* and *G. mosseae* were the predominant VAM species to be associated on castor crop in *chalka* (red sandy loams) soils of Andhra Pradesh. In normal to alkaline soils, the predominant VAM species found in the castor rhizopshere were *Glomus. mosseae*, *G. microcarpum* and *G. macrocarpum*. The present review shows potential possibility of using VAM for improving castor productivity in marginally fertile soils.

Keywords: Castor, VAM, and Phosphorus

India accounts for nearly 59% of the world's area and 81% of the world castor production and ranks first in both area and production in the world. Castor productivity in India is more than the world average and it ranks first among the major producing countries viz., China and Brazil. Although castor is grown in almost all the states, Gujarat, Andhra Pradesh, Tamil Nadu, Rajasthan and Karnataka are major states in descending order.

Castor can be grown on any type of soil. In the Telengana part of Andhra Pradesh, it is grown in chalka soils, which are red sandy loam to very sandy with hardly 10% clay and poor in nutrient status and water retentive capacity. The main castor growing districts are Ranga Reddy, Mahaboobnagar, Nalgonda and Medak. In Gujarat, it is grown on fertile and deep alluvial soils under irrigation. In Uttar Pradesh it is grown on heavy loams. Phosphorus (P) is essential for root growth, seed and fruit development and for early ripening. It is a constituent of several organic compounds including oils and amino acids. Phosphorus deficiency retards plant growth, root growth and delay in flowering. The P recommended for rainfed castor varies from 15 to 40 kg P_2O_5 /ha as per fertility and moisture retention status of soil. The red soils where castor is cultivated in Andhra Pradesh are deficient in available N and highly deficient in available P and zinc. Productivity of these soils is low due to low water holding capacity, soil erosion, nutrient runoff losses, organic matter depletion, poor native fertility, deficiencies of micro nutrients and sulphur, soil crusting and hardening.

Many researchers have shown that the productivity of castor could be improved by various agronomic manipulations in the red soils *viz*., applying balanced fertilizers and manures (Bheemaiah *et al*., 1998 and Hegde, 1998); by improving moisture conservation (Baby and Bapi Reddy 1997 and Subba Reddy *et al*., 1996), proper weed management (Reddy *et al*., 1993 and Sreedevi *et al*., 1997) and by using phosphate solubilizers (Arangarasan *et al*., 1999 and Baby and Bapi Reddy, 1998).

The research literature pertaining to the use of vesicular-arbuscular mycorrhizas (VAM) in improving the P nutrition of castor crop grown in India is hardly available. However, it is known that occurrence of VAM is ubiquitous and they are known to increase the P and moisture uptake in all agricultural crops. Plants infected with mycorrhizal fungi exhibit significant increase in the yield as compared with non-mycorrhizal plants. There are a few reports of VAM on groundnut, soybean, sunflower and sesame.

VAM and castor: The identity of VAM, their development in the root system and spore count corresponding to castor rhizosphere was studied decades back (Sulochana and Manoharachary 1989). Investigations in red *chalka* soils in Rajendranagar (pH 7.3, MHC 20%) were carried. Based on the observations of rhizosphere soil samples and root infection study of small castor roots at 30, 60 and 90 days after sowing, it was confirmed that the association of VA mycorrhizas in castor grown in semi-arid tropical soils. The roots were infected with mycorrhiza from early to mature stages with the age of host plant (Table 1). This rapid development of VAM fungi in castor was related to the increased vegetative growth of the host plant and due to the availability of adequate moisture, suitable pH, available nutrients and root exudates. It was shown that castor had supported eight VAM fungi of which *Glomus fasciculatum* and *Glomus constrictum* were predominant in *chalka* soils. In another report, where castor, fenugreek and maize were studied as a host crop for different VAM species inoculated in two soil conditions (i.e. normal and alkaline), it was found that castor to be the best host plant on normal soil (Table 2). However, the germination and survival % of castor was highly affected in the alkalinity conditions (Kashyap *et al*., 2005). VAM infectivity varied among different plant species depending upon fungal characteristics, host plant, type of soil and environmental conditions. It is believed that volatile exudates from the host plant are involved in stimulation of mycorrhizae spore germination, germ tube growth and directionality. Also, water-soluble exudates may provide the fungi with energy-containing compounds or essential nutrients to stimulate branching and allow the fungus to colonize the plant. Based on research reviewed so far, ample scope is still left to utilize the nature's most essential and beneficial symbiotic fungi VAM for improving productivity of castor.

Conclusions: The available literature suggests the positive association of vesicular arbuscular mycorrhiza with castor crop, the scope of using VAM in improving the P nutrition of castor crop grown in P deficient soils and for improving its productivity. It has been highlighted that *Glomus fasciculatum* and *Glomus constrictum* were predominant VAM species found in *chalka* soil (red soil of AP) and *Glomus mosseae, Glomus microcarpum* and *Glomus macrocarpum* species were found to dominate in normal to alkaline soil conditions when castor was grown as host plant. The available information provides ample scope for research in exploiting VAM in castor.

Table 1 VAM infection in castor root (%) and number of spores in rhizosphere soil

Sampling time (DAS)	Root infection (%)	Spore count/ 100g soil		
		G. fasiculatum	*G. constrictum*	*G. mosseae*
30	40	30	25	10
60	60	55	40	25
90	75	80	65	30

(Source: Sulochana and Manoharachary, 1989)

Table 2 VAM fungi on castor host plant in different soil conditions

Soil conditions	VAM infection (%)	Spore count/ 100g soil
Normal soil (pH 7.5)	100 ± 0	113 ± 3.0
Alkaline soil (pH 9.0)	70 ± 8.0	80 ± 8.0

(Source: Kashyap *et al*., 2005)

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Conservation agriculture for sustainable castor, *Ricinus communis* L. production

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Abstract

One of the important reasons for low productivity of castor is its cultivation in marginal and sub-marginal lands having poor soil quality i.e. shallow depth, low in organic matter content and poor fertility. These soils (mostly Alfisols) are susceptible to soil erosion and retain less water resulting in drought-like conditions leading to poor castor productivity. Conservation agricultural practices *viz.*, minimum tillage, crop residue management and cover crops play an important role in initiating changes in soil physical, chemical and biological properties, which in turn improve the crop yields. Conservation agriculture can be seen as a new way forward for conserving resources and enhancing productivity to achieve the goals of sustainable agriculture. However, it demands a strong knowledge base and a combination of institutional and technological innovations.

Keywords: Conservation agriculture, Alfisols, castor, tillage, residue management, cover crops

Introduction

Castor (*Ricinus communis* L.) occupies an important place in the country's vegetable oil economy. During recent years, castor has emerged as a commercial crop with immense export potential earning valuable foreign exchange. It ideally suits dryland farming in rainy season and with limited irrigations in post-monsoon both in traditional and non-traditional areas. Castor is considered to be a good contingent crop in case of monsoon aberrations providing a cushion to resource-poor farmers of rainfed areas.

India accounts for 60 % of global castor area and 68 % of world castor production and ranks first in area and production in the world (2008-09). India meets more than 70 % of world requirement of castor oil and its derivatives and earned nearly Rs. 2253 crores during 2008-09 through exports. The current castor production in the country is 11.71 lakh tonnes harvested from 8.66 lakh ha with a productivity of 1352 kg/ha (2008-09). However, wide regional disparities are encountered in yield of this crop with the highest being in Gujarat (1964 kg/ha) and lowest in Andhra Pradesh (509 kg/ha). As is evident from frontline demonstrations in the castor growing states, there exists large yield gap, which needs to be bridged through concerted research and extension efforts.

Castor production constraints

Despite phenomenal increase witnessed in the production and productivity over the last two decades, there are wide regional disparities in the productivity of castor. With the exception of Gujarat and Rajasthan, where the productivity has registered a six fold increase since 1970, the general productivity level of rainfed castor in all other parts of the country is very low. A multitude of factors such as its cultivation in sub marginal and marginal lands, uncertainty of rainfall and its erratic distribution, delayed sowings, poor management of the crop with little or no inputs and use of poor quality seed are responsible for low yields under rainfed conditions. Among the many constraints, poor soil quality and its management is the most important limiting factor for realizing the higher productivity of castor especially under rainfed conditions.

Characteristics of castor growing soils

Castor can be grown on any type of soils. In the Telangana part of Andhra Pradesh, it is grown on 'chalka' soils which are very sandy with hardly 10% clay and poor in plant nutrient status and water retentive capacity. It is grown on red sandy loams in the main castor growing districts of Ranga Reddy, Mahaboobnagar, Nalgonda and Medak. In Gujarat, it is grown on fertile, deep alluvial soils under irrigation. In Uttar Pradesh, it is grown on heavy loams.

The red soils (Alfisols) where castor is grown in Andhra Pradesh and other southern states in the semi-arid tropics (SAT), are characterized by the lack of structural development. Responsible for this are the combined contributions of low contents of fine (clay-sized) particles particularly at the surface, inactivity of the prevailing clay minerals (kaolin, with varying but small proportions of 2:1 clays and sesqui-oxides), and low-intensive cropping systems which contribute less biomass to the soil. These factors are responsible for low organic matter content in these soils.

A major consequence of the lack or non-stability of aggregation is the tendency of these soils to display rapid surface sealing following rainfall and crusting with subsequent drying cycles. Thus, although the soils can be easily cultivated and tilled when wet, they become very hard and extremely difficult to work when dry. Tillage in too wet conditions results in excessive compaction, so that for producing optimum tilth there is a limited working soil moisture regime.

Alfisols in the SAT are quite different in various locations, the lack of consistent success in managing these soils under rainfed conditions may be largely explained by the collective contributions of several physical factors (El-Swaify *et al.*, 1985):

1. Inherently low water retention characteristics of the soil matrix, which often compounded by insufficient depth of the soil zone available for water storage.
2. Mechanical impedance problems that restrict crop root proliferation. These are overcome only temporarily by tillage.
3. Instability of surface structure that leads to reduction of surface roughness (useful for maximizing surface retention and infiltration) and enhancement of surface sealing and crusting. These induce excessive runoff, even early in the season, and directly affect seedling emergence. Localized droughts are also very likely in the seed environment, i.e. in ridges or beds into which water entry by infiltration is restricted by surface sealing. Crusted soil surfaces also undergo increased losses of water by evaporation.
4. For non-flat cultures, weakness of installed land configurations is common with easy failure of ridges or beds, and excessive concentrations of induced runoff in the furrows which then undergo riling and exaggerated erosion.
5. The dry state of the soil as well as a high level of stoniness occasionally deters effective land preparation.

Because of the above limitations, particularly available water storage, rainfed utilization of SAT Alfisols is primarily restricted to the rainy season. From the chemistry and fertility viewpoint, Alfisols are generally quite low in fertility but this depends on their clay content, mineralogy and content of organic matter. Soil cation exchange capacity values range between 1 and 10 meq/100 g. Because of these low values, organic matter plays an important role in determining the nutrient status of Alfisols. The lack of active clays also indicates that organic matter must play an important role in controlling soil structural characteristics; this is one important reason why management of Alfisols for sustained agricultural productivity appears more readily achievable in the humid tropics compared to SAT. The erodibility of Alfisols appears to vary widely; the universal soil-loss equation's K value has been reported to be as high as 0.4 or more indicating that the soils are quite susceptible to erosion by water.

Conservation agriculture - A possible solution

There is considerable potential to enhance the productivity of castor in these soils under rainfed conditions. Realizing this potential essentially hinges on our ability to reverse the process of degradation - processes that will contribute to institutionalize water conservation, reduced runoff and erosion. Thus, resource conservation issues represent an essential prerequisite to achieve enhanced productivity (Abrol and Sangar, 2006).

Issues of resource conservation have assumed importance in wide-spread resource degradation problems, need to reduce production costs, increased profitability and make the agriculture more competitive and sustainable. Globally, growing concerns for sustainable agriculture have been seen as a positive response to limits of both low-input traditional agriculture and intensive modern agriculture relying on high levels of inputs for crop production. Sustainable agriculture relies on practices that encourage natural regenerative processes (e.g. nutrient cycling, soil regeneration and protection of natural enemies of pest and diseases) and maintain ecological equilibrium, preserve biodiversity and safeguard the environment.

Conservation agriculture (CA) has emerged as a new paradigm to achieve goals of sustainable agricultural production (Sangar and Abrol, 2005). It is a major step towards transition to sustainable agriculture. The term CA refers to the system of raising crops without tilling the soil while retaining crop residues on the soil surface. In broader sense, CA includes all those practices of agriculture, which help in conserving the land and environment while achieving desirably sustainable yield levels. CA practices refer to resource-conservation technologies (RCT) with the following characteristics (Harrington and Erenstein, 2005):

- A minimum level of soil movement, e.g., reduced or zero tillage
- Soil cover, particularly through the retention of crop residues on the soil surface
- Sensible, profitable crop rotations by including cover crops.

Combining the above elements with improved land-shaping (e.g. through laser aided leveling, planting crops on beds, etc.) further enhances the opportunities for improved resource management. In conventional systems, while soil tillage is a necessary requirement to produce a crop, tillage does not form a part of this strategy in CA. Intensive tillage in conventional system causes gradual decline in soil organic matter content through accelerated oxidation, resulting in reduced capacity of the soil to regulate water and nutrient supplies in plants. Burning of crop residues, a common practice in many areas (e.g. rice-wheat cropping system) further causes pollution, green house gas (GHG) emission and loss of valuable plant nutrients. When crop residues are retained on the soil surface in combination with no tillage, it initiates processes that lead to improved soil quality and overall resource enhancement (Bhale and Wanjari, 2009).

Conservation tillage

Conservation tillage is described as non-inversion tillage that leaves a significant fraction of crop residue on or only shallowly incorporated into the soil to control erosion, reduce energy use, and conserve soil and water. Stubble mulch, eco-fallow, no-till, direct drilling, and trashy-fallow are all forms of conservation tillage. Tillage for cereal grains is usually performed with unidirectional disks or sweeps that undercut the residue without substantial burial.

The effects of conservation tillage on various soil properties, organic matter status, soil nutrient status and environmental quality have been comprehensively reviewed by Blevins and Frye (1993). From the various reviews, it is understood that no single tillage system is suitable for all soils and climatic conditions. The predominant advantages of the conservation agriculture have been found in terms of reduced soil erosion, maintain, restoring and improving soil organic carbon (SOC) status in various production systems, hence more suited and required in rainfed agriculture. Thus, improved soil quality will be able to sustain castor productivity over a period of time.

Crop residue management

Drop in soil organic matter due to limited return of organic biomass owing to residue burning/removal has been identified as one of the key factors for unsustainability of the system. Burning of crop residues due to lack of efficient and user-friendly technologies for in-situ recycling not only leads to loss of considerable amount of N, P, K and S but also contributes to the global NO_2 and CO_2 budget and destruction of beneficial micro-flora of the soil.

Crop residue inputs play an important role in setting new organic matter equilibrium in soil. The effect of crop residue on soil organic matter is highly related to the amount and only weakly related to the type of residue applied (Rasmussen and Collins, 1991). Management of crop residues in zero till systems have been a challenge for the researchers and farmers with the tyne type openers. Sufficient efforts are being made during the recent past to develop the efficient technologies but development of new generation drills has been proved to be the most significant achievement in the direction of conservation agriculture. Sharma *et al.* (2003) reported that continuous applications of organics (straw, compost and Glyricidia leaves) with low till system improved soil quality, enhanced water use efficiency and crop productivity of rainfed soybean grown in Vertisols of central part of India. Similar improvement of soil properties and crop productivity due to crop residue incorporation and tillage operations was reported under rainfed conditions of Maharashtra (Reddy *et al.*, 2002) and in red soils of Madhya Pradesh (Narayan and Lal, 2009). Similar efforts to incorporate the crop residues or its compost products to the soil for enhancing soil quality and improving castor productivity should be explored through concerted research endeavours.

Cover crops

A permanent soil cover is important to protect the soil against the deleterious effects of exposure to rain and sun, to provide the macro and micro organisms in the soil with constant supply of food and alter the micro-climate in the soil for optimum growth and development of soil organisms, including plant roots. Cover crops need to be managed before planting the main crop. This can be done manually or with animal or tractor power. The important point is that the soil must always be kept covered. Since castor is widely spaced crop, there is possibility to grow inter crops which cover the soil during its crop period and their residue can be used as mulch after harvest. If soil moisture conditions permit, any leguminous crop such as cowpea (Vigna unguiculata), horse gram (Macrotyloma uniflorum) can be grown as cover crop after harvest of castor, so that soil can be protected. Apart from cover crops, the soil mulch has also been found quite effective in rainfed agriculture (AICRPDA, 2003). The effect of mulching is seen more in winter crops than in rainy season crops. The advantages of mulching is also seen where there was enough moisture in soils. Thus its usefulness was found limiting from moderate drought prone regions to less drought prone regions. Soil cover helps in:

- Improved infiltration and retention of soil moisture resulting in less severe, less prolonged crop water stress and increased availability of plant nutrients.

- Source of food and habitat for diverse soil life, creation of channels for air and water, biological tillage and substrate for biological activity through the recycling of organic matter and plant nutrients.
- Increased humus formation.
- Reduction of impact of rain drops on soil surface resulting in reduced crusting and surface sealing.
- Consequential reduction of runoff and erosion.
- Soil regeneration is higher than soil degradation.
- Mitigation of temperature variations on and in the soil.
- Better conditions for the development of roots and seedling growth.

Means and practices of conservation agriculture

- Use of appropriate/improved seeds for high yields as well as high residue production and good root development.
- Integrated management and reduced competition with livestock or other uses e.g. through increased forage and fodder crops in the rotation.
- Use of various cover crops, especially multi-purpose crops, like nitrogen-fixing, soil-porosity-restoring, pest repellent, etc.
- Optimization of crop rotation in spatial, timing and economic terms.
- Targeted use of herbicides for controlling weeds in conservation tillage.

Conclusions

Conservation agriculture (CA) has emerged as an effective strategy to achieve goals of sustainable agriculture especially for rainfed castor crop production. A shift in paradigm has become necessary in widespread problems of resource degradation associated with earlier strategies to enhance production with little concern for resource integrity. Accelerated development and adoption of CA technologies will call for greatly strengthened monitoring and evaluation along with policy research. Understanding constraints in adoption and putting in place appropriate incentives for adopting CA systems will be very important for achieving production sustainability.

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Studies on planting patterns in castor-based intercropping systems under rainfed conditions of Karnataka

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Abstract

A field experiment was conducted at Zonal Agricultural Research Station, Babbur Farm, Hiriyur during 2008 and 2009 to study the planting patterns in castor-based inter cropping systems under rainfed conditions of Karnataka. Paired row of castor + clusterbean in 2:4 row proportion recorded significantly higher plant height (151cm), total drymatter production (106 g/plant), primary spike length (28.8 cm) and average number of capsules (30/plant) and differed significantly over all other treatments except sole castor and paired row system of castor + groundnut in 2:4 row proportion. The yield of castor (1397 kg/ha) inter intercrop with four rows of clusterbean was comparable with sole castor (1416 kg/ha). The castor equivalent yields increased when castor was intercropped with clusterbean and groundnut. The land equivalent ratio (LER) (1.70) and B:C ratio (3.49) were highest in castor + clusterbean intercropping with 2:4 row proportion.

Keywords: Planting pattern, LER, CEY, castor, clusterbean

Introduction

Research priorities need to be focused on how to increase and sustain the crop productivity in rainfed areas (Rathore *et al.*, 2006). Castor is most preferred crop for rainfed areas because of its drought escaping mechanism with comparatively higher production ability under low soil fertility, soil moisture deficit with minimum inputs. It is a long duration crop with slow growing habit in the initial stages and it is grown in wider rows. These features offer a great scope to introduce short duration and quick growing legumes to exploit the land and resources more efficiently. This warrants an evaluation of the compatibility of intercropping in different planting patterns of castor. Several workers evaluated the influence of legumes and other intercropping in castor (Sri Latha *et al.* 2002 and Koli *et al.*, 2004). However the results of these investigations were inconsistent. Hence an experiment was conducted under rainfed conditions to know the profitable intercrops in different planting patterns of castor.

Materials and methods

Field experiment was conducted at Zonal Agricultural Research Station, Babbur Farm, Hiriyur, Karnataka during 2008 and 2009. The soil of experimental site was clayey in texture and slightly alkaline in reaction (8.0). The soil was medium in available nitrogen (282 kg/ha), available phosphorus (15 kg/ha) and high in available potassium (255 kg/ha). The organic carbon content was also medium (0.51%). The experiment was laid out in randomized complete block design consisting of 13 treatments of different sole and intercropping systems and replicated thrice. The treatments includes sole castor, castor + groundnut (1:3), castor + finger millet (1:3), castor + rainy season chickpea (1:3), castor + cluster bean (1:3), paired row of castor + groundnut (2:4), paired row of castor + fingermillet (2:4), paired row of castor + rainy season chickpea (2:4), Paired row of castor + clusterbean (2:4) and sole crops of groundnut ,finger millet clusterbean and rainy season chickpea. Furrows were opened with inter and intra row spacing of 90 cm and 45 cm for sole and 1:3 row proportion of castor intercropping systems. For paired row system of planting, two rows of castor were spaced at 60 cm with an inter row space of 120 cm between two pairs. Three rows of inter crops were sown in between two rows of castor and four rows of inter crops in between two pairs of castor (120 cm) with a basal application of 38 kg N, 38 kg P_2O_5, 25 kg of K in the form of urea, SSP and MOP/ha, respectively. Seed yield and green vegetable yields were recorded.

Results and discussion

Paired row system of castor + clusterbean (2:4) recorded significantly higher plant height (151 cm) and higher total dry matter (106 g/plant) of castor over all other treatments except sole castor (Table 1). Significantly lower plant height (136 cm) and total dry matter of castor (96 g/plant) was noticed with castor + fingermillet in 1:3 row proportion. The reduction in dry matter accumulation of castor when intercropped with finger millet was due to lower dry matter production ability. Similarly sole castor recorded significantly higher primary spike length (29.4cm) and average number of capsules (31/plant) as compared to other treatments except paired row system of castor + clusterbean (28.8 cm and 30 per/plant) and paired row system of castor + groundnut (28.7 cm and 29/plant) and significantly lower spike length and average number of capsules/plant was noticed in castor + finger millet in 1:3 row proportion. The castor grown in paired rows had no significant influence on the primary spike length and average number of capsules/plant. Thus, pairing of rows did not increase the intraspecific competition and provided a scope to accommodate more number of rows of intercrops components than in castor sown in equi-distant rows. Similar results were reported by Sri Latha *et al.* (2002) in castor leguminous intercropping system.

The mean seed yield of sole castor (1416 kg/ha) was being higher than that in the rest of intercropping system (Table 2). Next best treatment for castor seed yield was castor + cluster bean in 2:4 row proportion followed by castor + groundnut in 2:4 row proportion. The reduction in seed yield of castor when intercropped with finger miller was comparatively high. Thus with the leguminous crops like clusterbean, groundnut and chickpea, higher castor yield were recorded compared to castor intercropped with fingermillet.

The castor equivalent yield was significantly greater in castor + clusterbean in 2:4 and 1:3 row proportions than sole crop of castor. Intercropping of castor with clusterbean in 2:4 row proportions was found to be profitable system. Similar results of castor + clusterbean intercropping, system was reported by Padmavathi and Raghavaiah (2004). Among different intercroppings, castor +clusterbean in 2:4 row proportion recorded higher land equivalent ratio (1:70) and B.C ratio (3.49) than other intercropping systems (Table 1).

Table 1 Growth and yield parameters of castor as influenced by planting patterns in castor-based intercropping system

Treatment	Plant height (cm)			Total drymatter (g/plant)			Primary spike length (cm)			Average no. of capsules/plant		
	2008	2009	Pooled	2008	2009	Pooled	2008	2009	Pooled	2008	2009	Pooled
Sole castor	155	150	153	114	102	108	29.7	29.0	29.4	32	30	31
Castor + groundnut (1:3)	144	142	143	106	95	101	28.1	27.4	27.8	29	28	29
Castor + fingermillet (1:3)	139	133	136	101	90	96	24.8	24.0	24.4	26	24	25
Castor + rainy season chickpea (1:3)	143	138	141	105	94	100	27.9	27.1	27.5	28	27	28
Castor + clusterbean (1:3)	146	143	145	107	90	99	28.2	27.5	27.0	29	28	29
Paired row of castor + groundnut (2:4)	150	143	147	111	100	106	29.1	28.3	28.7	30	28	29
Paired row of castor + fingermillet (2:4)	143	136	140	104	92	98	26.1	25.6	25.9	28	27	28
Paired row of castor+rainy chickpea (2:4)	147	142	145	108	95	102	28.2	27.4	27.8	30	28	29
Paired row of castor + clusterbean (2:4)	152	149	151	112	100	106	29.1	28.5	28.8	31	29	30
SEm+	2.5	2.2	2.8	0.9	0.72	0.96	0.4	0.25	0.38	0.5	0.7	0.8
CD (P=0.05)	7.5	6.6	8.1	2.69	2.11	2.88	1.3	0.75	1.10	1.5	2.1	2.4

Table 2 Yield and economics as influenced by planting patterns in castor-based intercropping systems

Treatments	Castor seed yield (kg/ha)			CEY (kg/ha)			LER			B:C Ratio		
	2008	2009	Pooled	2008	2009	Pooled	2008	2009	Pooled	2008	2009	Pooled
Sole castor	1434	1398	1416	1434	1398	1416	1.00	1.00	1.00	2.50	2.60	2.55
Castor + groundnut (1:3)	1314	1253	1284	2102	1947	2040	1.66	1.63	1.65	2.78	2.71	2.75
Castor + fingermillet (1:3)	1175	1132	1154	1638	1665	1652	1.43	1.42	1.43	2.72	2.80	2.76
Castor + rainy season chickpea (1:3)	1272	1225	1249	1974	1793	1884	1.68	1.67	1.68	2.75	2.65	2.70
Castor + cluster bean (1:3)	1334	1323	1329	2345	2371	2358	1.69	1.65	1.67	3.02	3.49	3.26
Paired row of castor + groundnut (2:4)	1400	1334	1367	2136	1970	2053	1.67	1.62	1.62	3.00	2.92	2.98
Paired row of castor + fingermillet (2:4)	1258	1219	1230	1692	1767	1730	1.45	1.49	1.47	2.85	3.00	2.93
Paired row of castor + rainy chickpea(2:4)	1351	1300	1326	1999	1854	1927	1.69	1.70	1.69	2.95	2.77	2.86
Paired row of castor + cluster bean (2:4)	1417	1377	1397	2380	2421	2400	1.71	1.68	1.70	3.36	3.63	3.49
SEm+	27.1	35.99	34.96	27.56	28.25	29.65						
CD (P=0.05)	81.2	107.9	100.5	82.64	84.75	88.95						

CEY = Castor equivalent yield; LER = Land equivalent ratio

Sole crop yields (kg/ha) : Groundnut (975 and 897) , Fingermillet (1961 and 1795), Rainy chickpea (840 and 764) and Clusterbean (4920 and 45850) during 2008 and 2009, respectively.

Based on the investigation it could be inferred that, four rows of clusterbean can be intercropped in paired row of castor (60-120-60 cm) for maximising the productivity and profitability under rainfed conditions.

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Response of castor, *Ricinus communis* L. to sulphur application under irrigated conditions

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Abstract

The response of irrigated castor to sources and levels of sulphur was studied on loamy sand soils at Agricultural Research Station, Mandore, Jodhpur from 2003-04 to 06-07. Pooled data reveal that application of sulphur @ 20 kg/ha through gypsum produced maximum seed yield, net return and B:C ratio of 2767 kg/ha, Rs. 26494/ha and 2.29, respectively. The oil content of castor was not influenced by sulphur application however, the maximum oil yield of 1359 kg/ha was obtained with 20 kg S/ha applied through gypsum. Sources of sulphur had non significant effect on seed and oil content of castor.

Keywords: Castor, sulphur, sources, levels, oil content, seed yield, oil yield

Introduction

Castor (*Ricinus communis* L.) is mainly valued for important bio-degradable industrial oil. Castor oil is used for deriving products like dyes, detergents, plastics, printing ink, patent leather, ointment, polishes, paints, lubricants and hydraulic fluids. Castor cake is excellent organic manure too. India meets >70% of world's requirement of castor oil and earned foreign exchange of Rs. 2000 crores through export of castor oil during 2008-09. Despite these facts, the productivity of castor grown in 8.01 lakh ha area in country is only 1392 kg/ha (Anonymous, 2010). Excess use of inorganic fertilizers, limited use of manures and heavy uptake of nutrients by crop are some reasons of poor productivity. The major castor growing area in country lies in the states of Gujarat and Rajasthan where soil is light textured having low to medium sulphur (S) content. Sulphur has emerged as fourth most important nutrient in plants. Sulphur is required for the formation of chlorophyll, proteins and oil in plants. It is involved in the formation of glucosides, glucosinolates and sulphydral (SH-1) linkages. It is constituent of three essential amino acids (cysteine, cystine and methionine) which are the building blocks of protein. Sulphur also activates the enzymes which aids in bio-chemical reactions within the plant (Tandon and Merrick, 2002). Research work on the role of S in edible oilseeds is well recognized but effect of S on the non edible, long duration oilseed crop like castor is meagre. Hence this trial was conducted.

Materials and methods

The field experiment was conducted at Agricultural Research Station, Mandore (Jodhpur) during four consecutive seasons from 2003-04 to 2006-07. The soil of the site was loamy sand in texture with low available nitrogen (157 kg/ha), medium available phosphorus (32 kg/ha), potassium (394 kg/ha) and sulphur (13 mg/kg). Ten treatment combinations comprising of 3 levels (10, 20 and 30 kg/ha) and 3 sources of sulphur (gypsum, elemental sulphur and single super phosphate) including control were tried in randomized block design with 3 replications. The net plot size was 3.6 m x 6.0 m. Castor hybrid RHC-1 was sown in the 2^{nd} fortnight of July every season at 90 cm row-to-row and 60 cm plant-to-plant spacing. Seeds treated with Apron SD @ 6 g/kg seed were sown 3 cm deep through dibbling. Recommended package of practices for castor crop were followed. Harvesting of spikes was done through 6 pickings at one month interval starting from 90 days after sowing (DAS). Oil analysis was done from the seed sample taken from first pick at 90 DAS.

Results and discussion

The highest seed yield of 2767 kg/ha was obtained with application of 20 kg S/ha applied through gypsum which was significantly superior over 10 kg S/ha applied through single super phosphate, gypsum, elemental sulphur and control by 22.8, 18.5, 22.2 and 30.8%, respectively (Table 1). Sulphur had no significant effect on plant stand, plant height and spikes/plant but 100 seed weight was improved significantly by 7.1% with application of 30 kg S/ha through single super phosphate. Similarly spike length was enhanced significantly by adding 20 kg S/ha either through gypsum or single super phosphate by 4.0 and 4.3 cm, respectively.

The increase in seed yield is mainly ascribed to improvement in yield attributes with S fertilization. Sulphur fertilization increased available S status of the soil and growing crop without S input will decrease (Intodia and Sahu, 1999). Murthy and Muralidharudu (2003) reported that sulphur is one of the limiting nutrients in reducing castor seed yield in red *chalka* soil (Alfisol) of Andhra Pradesh and its application will increase the S bio-availability. The sources of sulphur had no significant effect on the yield attributes as well as on seed yield of castor. Similar findings have been reported by Kumar *et al.* (2001) in mustard and Patel *et al.* (2009) in groundnut.

Oil content of castor was not influenced by S application. However, the highest oil yield of 1359 kg/ha was obtained with 20 kg S/ha through gypsum which was higher over 10 kg S/ha applied through single super phosphate, gypsum, elemental sulphur and control by 283, 238, 280 and 358 kg/ha, respectively.

Owing to higher castor bean yield and low cost of gypsum, the highest net return (Rs. 26494/ha) and B:C ratio (2.29:1) were recorded with 20 kg S/ha applied through gypsum (Table 1). This was closely followed by 30 kg S/ha applied through gypsum *(Rs. 26187/ha and 2.27:1, respectively). Application of sulphur @ 20 kg /ha and 30 kg/ha applied through gypsum* resulted in an increase of net return by Rs. 10690/ha and Rs. 10997/ha over no sulphur, respectively. It is therefore, concluded that application of 20 kg S/ha through gypsum is a beneficial practice in castor crop grown under the prevailing soil and agro-climatic condition of western Rajasthan.

Table 1 Seed, oil yield and economics of castor as influenced by doses and sources of sulphur under irrigated condition (Pooled data of season, 2003-04, 2004-05, 2005-06 and 2006-07)

Treatment		Plant stand ('000/ha)	100 seed wt. (g)	*Plant* height (cm)	*Spike* length (cm)	Spikes /plant	*Seed* yield (kg/ha)	Oil (%)	Oil yield (kg/ha)	*Net* return (Rs./ha)	B:C ratio
S Dose (kg/ha)	Source										
Control	-	18.1	23.9	64.0	42.0	12.5	2116	47.3	1001	15497	1.76
10	SSP	18.1	24.7	66.5	43.4	12.9	2253	47.9	1079	17777	1.87
10	Gyp.	17.7	24.8	66.0	41.5	13.4	2336	48.0	1121	19202	1.94
10	ES	18.1	24.6	66.0	42.7	13.3	2265	47.5	1076	17893	1.87
20	SSP	19.0	25.1	63.0	46.3	14.4	2589	48.9	1266	23419	2.14
20	Gyp.	17.1	25.2	62.5	46.0	14.7	2767	49.1	1359	26494	2.29
20	ES	18.5	25.4	65.0	44.0	14.2	2628	48.2	1267	23919	2.15
30	SSP	18.8	25.6	65.5	45.2	14.5	2732	48.3	1320	25786	2.25
30	Gyp.	17.9	24.9	63.5	45.4	14.2	2751	48.8	1342	26187	2.27
30	ES	18.4	25.1	63.5	45.7	14.2	2608	48.4	1262	23454	2.12
SEm ±		0.3	0.5	2.5	1.2	0.8	92	0.6	-	-	-
CD (P=0.05)		NS	1.5	NS	3.5	NS	260	NS	-	-	-

SSP=Single super phosphate, Gyp.=Gypsum, ES= Elemental sulphur

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Response of castor varieties to spacing and nipping in Alfisols of southern dry region of Karnataka

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Abstract

A field experiment was conducted to study the response of castor varieties to spacing and nipping in Alfisols of *southern dry region of Karnataka at the dryland agriculture centre, GKVK, Bengaluru during rainy season of 2007* and 2008.The experiment was laid out in split-split plot design with two varieties in the main plots, three spacing in the sub-plots and nipping in the sub-sub-plots and replicated thrice. The pooled analysis indicated that significantly higher seed yield of castor was obtained in DCH-177(1298 kg/ha) at a spacing of 120 cm x 45 cm compared to DCS-9 with higher B:C ratio (1.73). Significantly higher seed yield was obtained in nipped plots (1423 kg/ha) as compared to non-nipped plots (958 kg/ha) due to more number of capsules/spike and more length of the

spike with less per cent chaffiness. DCH-177, 120 cm x 45 cm and nipping were interacted and produced higher seed yield.

Keywords: Nipping, castor varieties, spacing, Alfisols

Introduction

Castor (*Ricinus communis* L.) is an important non-edible, export oriented industrial oilseed crop in India, It has a prominent place in drylands due to its drought resistance mechanism through quick growth, deep root system and wax coating on shoots. In India the crop occupies 7.87 lakh ha with an annual production of 10.54 lakh t with a productivity of 1339 kg/ha. In Karnataka, the area under this crop is 23,000 ha with an annual production of 16,000 t and a productivity of 696 kg/ha (FAO, 2007). About 1.45 lakh tonnes of castor oil is being exported from India earning a foreign exchange of Rs. 2.97 crores.

Since the crop is perennial in nature and indeterminate growth habit, it tries to put forth lot of vegetative growth with numerous spikes. Thus, there will be uneven source-sink relationship resulting in poor capsule filling, chaffiness, leading to yield reduction, besides the staggered maturity of the spikes. Under prolonged humid conditions during monsoon, the crop tends to uninhabited branching and canopy overlapping lead to heavy infestation of *Botrytis* (grey rot) fungal disease especially in spikes reduces seed yield. In castor, maintenance of source to sink relationship is very important rather than allowing more vegetative growth presumably for more yield. Hence, staggered nipping i.e. removal of auxiliary buds by retaining only one/spike assumes importance in maintaining optimum source to sink relationship.

Materials and methods

The field experiment was conducted at All India Coordinated Research Project for Dryland Agriculture, GKVK, University of Agricultural Sciences, Bengaluru during rainy season of 2007 and 2008 with a plot size of 6.3 m x 14 m. The experiment was laid out in split-split plot design with three replications. Castor genotypes (cv. DCS-9 and DCH-177) in the main plots, spacing (90 cm x 45 cm, 120 cm x 45 cm and 180 cm x 45 cm) in the sub-plots and nipping (nipping and no nipping) in the sub-sub-plots. Nipping of castor was done once in a week starting from 40 days or soon after emergence of first spike and continued till five spikes/plant emerged in plots received nipping treatment.

Results and discussion

Significantly higher seed yield of castor was recorded in DCH-177 (1298 kg/ha) as compared to DCS-9 (1083 kg/ha). Among different spacings, castor grown with 120 cm x 45 cm recorded significantly higher seed yield (1408 kg/ha) followed by 90 cm x 45 cm (1164 kg/ha) and 180 cm x 45 cm (999 kg/ha). Staggered nipping in castor reduced vegetative growth and removed unwanted spikes; it also recorded significantly higher seed yield of castor (1423 kg/ha) as compared to non-nipped castor (958 kg/ha) (Table 1). Higher B:C ratio was obtained in DCH-177 (1.73), 120 cm x 45 cm spacing (1.72) and in nipped plots (1.83) (Table 2). Baby Akula and Bapi Reddy (1998) observed that performance of castor genotypes under different sowing dates during rainy season showed 15th June seeding was better than delayed sowing and GCH-4 out yielded Aruna, Jyothi and Kranti under rainfed condition.

Table 1 Pooled analysis (2007 and 2008) of seed yield, yield components and chaffiness in castor as influenced by varieties, spacing and staggered nipping

Treatments	Seed yield (kg/ha)	Spikes/ plant	Spike length (cm)	Capsules/spike	Chaffiness (%)
Varieties					
DCH-177	1298	6.86	38.47	63.1	29
DCS-9	1083	6.80	32.43	48.0	30
SEm.±	16.6	0.25	0.90	1.8	2.0
CD (P=0.05)	47.2	NS	2.58	5.1	NS
Spacing (cm)					
90 x 45	1164	7.08	35.60	54.0	28
120 x 45	1408	6.83	36.37	56.0	27
180 x 45	999	6.58	34.42	57.0	32
SEm.±	20.3	0.30	1.14	2.2	2.5
CD (P=0.05)	57.7	NS	NS	NS	NS
Nipping					
Non –nipping	958	9.27	29.74	42.0	50
Nipping	1423	4.38	41.16	69.0	9
SEm.±	16.5	0.24	0.90	1.8	2.0
CD (P=0.05)	47.1	0.68	2.58	5.1	5.8

Staggered nipping in dry lands reduced vegetative growth and removed unwanted spikes. The chaffiness in castor spikes was lower in nipped plots (9%) as compared to non-nipped plots (50%) (Table 1). Between two varieties, DCH-177 performed better than DCS-9. A spacing of 120 cm x 45 cm proved to be ideal as compared to other two spacing and had given higher seed yield. The seed yield was significantly higher in the nipped castor plots in all the three levels of spacing. Shivaramu and Krishna Murthy (2008) reported from Bengaluru that nipping in early sown castor crop gave higher seed yield (2806-2974 kg/ha) as against that of no nipping (1491-1542 kg/ha). However, delayed sowing reduced the seed yield of castor drastically. Nipping in delayed sown crop did not show significant impact on growth and yield of castor. The crop remained almost free from *Botrytis* and *Alternaria* diseases in early sown nipped castor. The severity of the diseases in non-nipped castor was high particularly in late sown castor due to profuse vegetative growth and crowding effect.

DCH-177, 120 cm x 45 cm spacing and nipping were interacted and produced higher seed yield (1774/ha). Raghavaiah (1999) reported that DCH-177 and DCH-171 performed better at wider spacing of 90 cm x 30 cm or 90 cm x 45 cm than at close spacing and early sowing. It is concluded that DCH-177 at a spacing of 120 cm x 45 cm with staggered nipping produced significantly higher seed yield of castor in Alfisols due to more spike length, more number of capsules/spike and less chaffiness percentage resulting in higher economic returns (Table 2).

Table 2 Economics of castor as influenced by varieties, spacing and staggered nipping (mean data)

Treatments	Cost of cultivation (Rs./ha)	Gross Returns (Rs./ha)	B: C ratio
Varieties			
DCH-177	15113	26507	1.73
DCS-9	14685	20010	1.34
Mean	14899	23258	1.53
Spacing (cm)			
90 x 45	15436	23501	1.50
120 x 45	15245	26715	1.72
180 x 45	14015	19560	1.37
Mean			1.53
Nipping			
Non –nipping	14149	17630	1.23
Nipping	15649	28887	1.83
Mean			1.53

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Response of castor to varying levels of nitrogen and phosphorus application under rainfed conditions

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Abstract

Field studies conducted during rainy season with castor hybrid GCH-4 revealed that application of 80 kg nitrogen and 40 kg phosphorus/ha was found to be adequate for higher productivity of castor and net returns under rainfed conditions of Akola.

Keywords: Castor, nitrogen, phosphorus.

Introduction

Castor (*Ricinus communis* L) occupies an important place in the country's vegetable oil economy and emerged as commercial crop with great export potential earnings of valuable foreign exchange. Castor is considered to be a good contingent crop under delayed monsoon condition under rainfed areas. Improved varieties and optimum dose of fertilizer can considerably increase castor seed yield under rainfed condition (Sarma, 1985). However, information on the performance of high yielding varieties and hybrids of castor at different levels of nitrogen (N) and phosphorus (P) is limited specially under agro-climatic conditions of Vidarbha.

Materials and methods

A field experiment was conducted during rainy season 2008 at Department of Agronomy, Dr. P.D.K.V., Akola. The soil of the experimental site was clay loam in texture, slightly alkaline (pH 7.9) and low in available N (182.4 kg/ha), P_2O_5 (13.6 kg/ha) and high in available K_2O (454.8 kg/ha). The treatments consisting of levels of N (0, 20, 40, 60 kg/ha) and four levels of P_2O_5 (0, 20, 40 and 60 kg/ha) were evaluated in factorial randomized design with three replications. The test hybrid of castor GCH-4 was sown on 21 July 2008. The complete dose of phosphorus and half dose of nitrogen as per treatment was placed at 7 cm deep at the time of sowing and remaining half dose of N was applied after 30 days by ring method, when moisture was available in the soil. A common dose of 20 kg K_2O/ha was applied to all plots.

Results and discussion

Application of N resulted in significant increase in plant height up to primary spike at first harvest of castor. Number of spikes, capsules, seeds/plant and seed yield of castor was significantly influenced by successive increase in N level from 0 to 120 kg N. However, difference between 80 and 120 kg N/ha for growth and yield attributes and yield was at par. Increase in N levels appreciably enhanced the yield up to 80 kg/ha, which resulted in 26.2% more seed yield. The enhanced yield under 80 kg N/ha was owing to more availability of nutrient N, which helped in better growth and yield parameter resulting in higher yields. This increase in yield attributes might have been on account of overall improvement in vegetative character at highest level of nitrogen, which favourably influenced flowering and fruiting and ultimately resulted into increase in yield attributes. Similar results were reported by Rao and Venkateswarlu (1988).

Data on application of P_2O_5 indicated that plant height up to primary spike of castor and all yield attributes were increased significantly up to 40 kg/ha. The difference between 40 and 60 kg P_2O_5 was non significant. Increase in P_2O_5 levels appreciably enhanced the yield of castor up to 40 kg/ha, which resulted in 24.8% more seed yield. The seed yield and net returns increased significantly with application of 80 kg N and 40 kg P_2O_5/ha.

Based on the above findings it could be concluded that application of 80 kg N and 40 kg P_2O_5 will be the optimum for achieving the maximum productivity under rainfed conditions of Vidarbha.

Table 1 Plant height, spikes/capsule and seed yield of castor as influenced by N and P_2O_5 levels

Treatments	Plant height up to primary spike (cm)	No. of spikes/plant	No. of capsules/plant	No. of seeds/plant	Seed yield (kg/ha)	% increase over control	Net returns (₹/ha)
Nitrogen (kg/ha)							
N_0	119.8	5.7	147	267	1407	0.0	10344
N_{40}	128.5	6.3	163	308	1602	12.1	12820
N_{80}	135.3	6.6	181	346	1909	26.2	17221
N_{120}	136.8	6.7	184	349	1974	28.7	17527
CD (P=0.05)	6.7	0.3	8.4	7.05	109	-	1868
Phosphorus (kg/ha)							
P_0	118.6	5.8	148	269	1411	0.0	10602
P_{20}	129.3	6.3	165	306	1619	12.8	13169
P_{40}	134.7	6.5	178	346	1878	24.8	16646
P_{60}	137.7	6.6	184	351	1983	28.8	17494
CD (P=0.05)	6.7	0.3	8.4	7.05	109	-	1868
Interaction NxP							
CD (P=0.05)	NS	NS	16.8	14.10	219	-	3736

Table 2 Net returns (₹/ha) as influenced by N and P_2O_5 levels

Treatments	P_2O_5 levels (kg/ha)				
Nitrogen (kg/ha)	P_0	P_{20}	P_{40}	P_{60}	Mean
N_0	7683	11032	11776	10882	10344
N_{40}	11158	12466	13260	14420	12820
N_{80}	10764	15145	20441	22534	17221
N_{120}	12802	14034	21131	22140	17527
Mean	10602	13169	16646	17494	
CD (P=0.05)			3736		

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Physiological manipulation of sex expression in pistillate line of castor by chemicals

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Abstract

In parental line maintenance and hybrid seed production, manipulation of sex expression by using chemicals is of great importance in castor. The seed production of pistillate line VP-1 is generally taken up during rainy season to induce environmentally sensitive temperature dependant interspersed staminate flowers (ISF) character for its multiplication and maintenance. Studies were conducted at Main Agricultural Research Station, University of Agricultural Sciences, Raichur to know the effect of different chemicals on sex expression in pistillate line VP-1 of castor. The different chemicals /growth regulators were sprayed at 25 and 55 days after sowing (DAS). The results on effect of different chemicals in castor variety VP-1 revealed that spraying either GA_3 (50 mg/l) or $AgNO_3$ (50 mg/l) at 25 DAS and 50 DAS produced more interspersed staminate flowers , whereas, spraying either ethrel (100 mg/l) or GA_3 (25 mg/l) or $AgNO_3$ (75 mg/l) produced more pistillate flowers compared to control.

Keywords: Sex expression, pistillate line, chemicals, growth regulators

Introduction

Castor is an important oilseed crop in India fetching a sizeable amount of foreign exchange to the country by virtue of its export besides meeting internal demand of various industries such as soaps, paints, varnishes, synthetic detergents and wide range of chemical products. Indias's share in world's area and production of castor is 68% and 76% respectively (Pratap Kumar Reddy *et al.*, 2006).

Parent and hybrid seed production of castor being taken up by many seed producers in Hyderabad -Karnataka region on sizeable area during rainy and winter season respectively. The seed yield in female line VP-1 of castor hybrid GCH-4 is directly/indirectly influenced by several characters of which sex expression i.e., male and female flowers in a spike is very much important. The seed production of pistillate line VP-1 is generally taken up during rainy season to induce environmentally sensitive temperature dependant interspersed staminate flowers (ISF) character for its multiplication and maintenance. The pistillate character in castor is polygenically controlled, highly unstable, depending on input management levels, time of planting, nutrition, age of the plant and other environmental factors, it can be reverted to monoecism at any stage during sequential development of racemes. Though several modified methods of pistillate line multiplication is though practical but it has certain drawbacks namely, excessive dependant on environmentally sensitive ISF, problems associated with desiccating winds which are restricting the usage of this system, for multiplication of pistillate line during rainy season. To overcome this drawback, plant growth regulators can be applied to alter sex expression.

As per available literature, it is known that plant growth regulators can alter sex expression in cucurbits (Yang *et al.*, 1985) and castor (Shifriss, 1961). An increase in gibberellins is associated with maleness (Contliffe and Robinson, 1971). Hence an experiment was conducted to study the influence of exogenous application of chemicals namely gibberellic acid (GA_3), silver nitrate ($AgNO_3$), ethrel, urea and naphthalene acetic acid (NAA) at various concentrations were tried on sex expression in VP-1, pistillate line of castor during rainy season of 2007 and 2009.

Materials and methods

An experiment was conducted at main Agricultural Research Station, University of Agricultural Sciences, Raichur on pistillate line of castor i.e., VP-1 where the seeds were obtained from Gujarat. The sowing was carried out during August 2007 and 2009 using randomized block design replicated thrice. The chemicals were sprayed on 45 to 50 plants. The plot size was 5.4 m x 5.4 m with a spacing of 90 cm x 60 cm. The chemicals /growth regulators were sprayed at 25 and 55 days after sowing (DAS) as shown in Table 1.

Table 1 Influence of chemicals spray on production of pistillate (P) and staminate (S) flowers in different branches of castor cv. VP-1 (pooled data of 2007 and 2009 years)

Treatments	Branches									
	Primary		Secondary		Tertiary		Quaternary		Total	
	P	S	P	S	P	S	P	S	P	S
GA_3 25 mg/l	42	12	45	39	44	81	35	12	165.8	143.3
GA_3 50 mg/l	37	9	34	111	35	49	30	25	134.6	194.7
$AgNO_3$ 50 mg/l	35	47	37	157	36	98	32	17	139.8	318.3
$AgNO_3$ 75 mg/l	38	14	43	18	41	29	34	53	155.6	113.8
Urea 2%	29	5	33	7	31	38	30	23	123.3	72.2
Ethrel 100 mg/l	39	4.	43	5	41	5	34	5	155.5	19.2
MH 200 mg/l	34	10	33	9	34	7	27	6	127.2	31.5
NAA 50 mg/l	32	8	34	8	33	6	28	5	127.9	26.6
Control	34	7	37	7	36	6	27	5	133.6	24.5
Mean	35.5	12.9	37.7	39.9	36.6	35.3	30.6	16.7	140.3	104.9
SEm ±	1.7	0.1	1.8	0.3	6.0	2.2	1.5	0.2	8.2	0.5
CD (P=0.05)	5.3	0.3	5.5	0.9	18.0	6.6	4.5	0.6	24.8	1.6

Results and discussion

Total number of pistillate whorls were maximum with the application of GA_3 at 25 mg/l, $AgNO_3$ 75 mg/l and Ethrel at 100 mg/l when compared to control. Maximum average number of pistillate whorls seen in primary, secondary and tertiary compared to quaternary and late order spikes. It is evident from the results (Table 1) that GA_3, $AgNO_3$ and ethrel were effective chemicals for increasing female tendency in castor. These results are in confirmation with earlier findings of Shifriss (1961) and Ramesh *et al.* (2001).

The environmentally sensitive ISF play a key role in the maintenance of pistillate lines. However their expression during hybrid seed production in the pistillate parents results in impure plants their by certified seed lots are being rejected by the certifying agency. The present experimental results showed that the application of $AgNO_3$ at 50 mg/l recorded highest number of interspersed staminate flowers followed by GA_3 at 50 mg/l whereas ethrel suppressed the expression of ISF. Further, it was also noticed that secondary order spikes recorded maximum ISF followed by tertiary spike. The results on effect of different chemicals in castor variety VP-1 revealed that spraying either GA_3 (50 mg/l) or $AgNO_3$ (50 mg/l) at 25 DAS and 50 DAS produced more interspersed staminate flowers, whereas, spraying either ethrel (100 mg/l) or GA_3 (25 mg/l) or $AgNO_3$ (75 mg/l) produced more pistillate flowers compared to control.

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Bio-energetics of castor-based intercropping system

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Abstract

The studies on energetics of castor-based intercropping system indicated that the highest energy use efficiency (55.96 g/MJ x 10^{-3}) was recorded in castor + greengram (1:2). However, energy input-output ratio was maximum (20.86 MJ x 10^{-3}) under castor + cowpea (1:2).

Keywords: Castor equivalent yield, energy use efficiency

Introduction

Castor based intercropping finds an important place in the cropping system of dryland agriculture in semi-arid zone of India because of its deep root system, drought hardiness and slow initial growth, it allows the cultivation of shallow rooted, short duration legumes as a intercrops in castor and provides ample scope for growing intercrops in between the rows of castor to get more returns from a unit area of land. Now farmers of Vidarbha switch over to adopt this cropping system in some pockets considering foreign demand for various industrial purpose. The beneficial effects of intercropping in increasing and stabilizing the returns/unit area are well known.

Materials and methods

The present investigation was taken up to study the bio-energetics of castor-based intercropping system and was conducted in rainy season of 2009 at Agronomy Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in randomised block design with three replications. There were nine treatments comprised of castor as base crop and greengram, blackgram, soybean and cowpea were intercropped as additive series in 1:1 and 1:2 row proportion at 30 cm row spacing. Castor was sown at a spacing of 90 cm x 60 cm in sole as well as in intercropping system. Recommended fertilizer dose of 60:40:20 kg NPK/ha was given to castor and all intercrops. All the fertilizer was applied at the time of sowing. Net plot size was 5.4 x 4.2 m^2. The experiment was sown on 15 July, 2009. The crop-wise varieties used were castor cv. GCH-4, greengram cv. AKM-8802, blackgram TAU-1, soybean cv. JS-335, cowpea cv. Pusa Komal. The soil of thé experimental plot was medium black with pH 7.8. The distribution of the rainfall during the season was 464.4 mm which was marginally sufficient for growth of intercrops and post-monsoon rains of 97.8 mm, was helpful for satisfactory growth of castor after harvesting of intercrops. Energetics of intercropping were calculated as suggested by Mittal and Dhawan (1988).

Results and discussion

Seed yield of castor were reduced due to intercrop treatments. Significantly maximum seed yield were recorded under sole castor. Least reduction in the yield of castor due to intercropping with greengram, however, more reduction was observed when intercropped with cowpea in 1:2 row system over sole castor. The castor equivalent yield was maximum over sole castor and significantly highest (3665 kg/ha) recorded in castor + greengram 1:1 followed by castor + greengram 1:2 (3510 kg/ha) where as lowest castor equivalent yield (2325 kg/ha) was recorded with castor + soybean. These results were in agreement with Gangasaran and Giri (1983). Grain yield of intercrops were maximum in 1:2 row proportion than 1:1 row proportion because of low plant population of intercrops. Among the intercrops, maximum yield of cowpea was obtained due to green pods.

The value of energy input was highest in castor + soybean 1:2 (9131 MJ x 10^{-3}) while the lowest energy input recorded in sole castor (7781 MJ x 10^{-3}). Maximum energy output (174413 MJ x 10^{-3}) was more in castor + cowpea (1:1). The highest input output ratio (20.86) was observed in castor + cowpea (1:2) followed by castor + greengram (1:1) whereas minimum input output ratio (11.4) was found in castor + soybean (1:2). The maximum energy use efficiency (56 g/MJ x 10^{-3}) was noticed in castor + greengram (1:1) and minimum (31.7 g/MJ x 10^{-3}) in castor + soybean (1:2). Similar results were reported by Billore *et al.* (1986) that mean energy use efficiency was in castor + legumes intercropping system.

Table 1 Seed yield of castor, yield of intercrops and castor equivalent yield energy input, energy output, energy output-input ratio and energy use efficiency as influenced by various intercropping treatments

Treatment	Castor yield (kg/ha)	Intercrop yield (kg/ha)	Castor equivalent yield (kg/ha)	Energy input (MJ x 10^{-3})	Energy output (MJ x 10^{-3})	Energy input-output ratio	Energy use efficiency (g/MJ x 10^{-3})
Sole castor	2532	-	2532	7781	136907	17.6	32.5
Castor + greengram (1:1)	2325	763	3665	8058	136931	17	56.6
Castor + blackgram (1:1)	2270	608	3216	7958	134607	16.7	47.8
Castor + soybean (1:1)	2204	539	2793	8984	134620	15	37.3
Castor + cowpea (1:1)	2298	3800	2840	8359	174413	20.9	38.3
Castor + greengram (1:2)	2087	810	3510	8146	133701	16.4	56
Castor + blackgram (1:2)	1820	792	3053	8046	115162	14.1	47.6
Castor + soybean (1:2)	1478	663	2325	9131	103702	11.4	31.7
Castor + cowpea (1:2)	1871	4150	2463	8447	148871	17.6	33.8
CD (P=0.05)	154	-	308	402	3729	-	5.3

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Optimization of castor, *Ricinus communis* L. production under resource constraints in central dry zone of Karnataka

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Abstract

A field study was conducted at Zonal Agricultural Research Station, Babbur Farm, Hiriyur on medium black soil to identify the hierarchy of production factors for efficient use of resources for optimum production. The result revealed that adoption of full package of practices is highly remunerative in castor production. Non-adoption of weeding in castor is most critical factor followed by fertilizer and plant protection measures.

Keywords: Castor, full package, weeding

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop of India and is mainly valued for important bio-degradable industrial oil which is used for deriving products like dyes, detergents, plastics, printing ink, patent leather, ointment, polishes, paints, lubricants and hydraulic fluids. The productivity of castor in the country is 1396 kg/ha (Anonymous, 2009). Non-adoption of full package of practices due to higher cost of cultivation is the main cause for poor productivity of castor grown on low fertile light soils. Different factors (weeding, fertilizer and plant protection) contribute towards the establishment and growth of castor crop and ultimately the final seed yield. But, relative contribution of these factors has not been quantified in castor under rainfed condition in central dry zone of Karnataka. Hence, a field study was conducted to study the influence of different input factors alone or in combination on the productivity of rain fed castor to prioritize the components of whole package according to their contribution to seed yield is warranted. Under scarce condition, farmers can give maximum emphasis to these particular inputs which contributes maximum towards yield.

Materials and methods

A field experiment was conducted at Zonal Agricultural Research Station, Babbur Farm, Hiriyur, Karnataka during rainy season of 2009. The soil of the site was medium black having pH value of 7.7 with low available nitrogen (162 kg/ha), medium available phosphorus (16.2 kg/ha) and medium available potassium (270 kg/ha). The experiment was laid out in randomized block design with eight treatments replicated three times using castor hybrid DCH-177. The crop was sown in the 2nd fortnight of July at 90 cm x 60 cm spacing. The treatments consisted of T_1: Full package; T_2: T_1-Fertilizer; T_3: T_1-Plant protection; T_4: T_1-Weeding; T_5: T_1-(Fertilizer + plant protection); T_6: T_1-(Fertilizer + weeding); T_7: T_1-(plant protection + weeding); T_8: T_1- (plant protection + fertilizer + weeding) (Table 1). The total rainfall received during 2009 was 711.9 mm. Harvesting of spikes was done in three pickings at monthly interval starting from 90 days after sowing.

Results and discussion

It was observed that adoption of full package of practices produced significantly higher seed yield. This increase in seed yield was due to production of more spikes/plant, more capsules/spike and higher 100 seed weight. Studies conducted at Bawal, Gujrat, Kanpur, Mandor and Yethapur on optimization of castor production under resource constraints also indicated the need for adoption of full package of practices to obtain the highest seed yield of castor (Anonymous, 2009). Among the individual production factors, non adoption of weeding alone reduced yield considerably. Withdrawal of weeding allowed the weeds to grow for full crop period, which completely smothered the crop plants resulting in poor plant growth and consequently low yield. Length of primary raceme and spikes/plant were reduced significantly in all the treatments where weeding was not done. Severe competition with weeds produced castor plants with lower number of spikes, shorter raceme and suppressed plant growth which ultimately reflected in poor seed yield. Poor plant growth also allowed second flush of weeds in crop during winter season because there was no smothering effect of crop on new emerging winter weeds. Weed species, *Convolvulus arvense, Amaranthus viridis, Cynodon dactylon* and *Celosia argetia* in rainy season and *Chenopodium album, Achyranthus aspera* and *Hibiscus ponderiformis* in winter season dominated the unweeded plots.

Hence weeding emerged as the most important component of crop production in castor under rain fed condition in the central dry zone of Karnataka. At S.K. Nagar (Gujarat), non-adoption of weeding suppressed castor yield significantly by 2169 kg/ha closely followed by non-adoption of fertilizer input (1322 kg/ha) thus providing their importance in castor production (Anonymous, 2007).

Withdrawal of fertilizer from full package (T_2) reduced the yield level by 660 kg/ha, whereas, non-adoption of plant protection measures (T_3) from full package reduced the yield by 737 kg/ha. No fertilization to castor grown on black soil which is poor in available nitrogen, medium in phosphorus and potassium directly affected the plant growth and there by the seed yield. This indicates that fertilizer is the next most important factor after weeding to enhance productivity of castor under rainfed crop culture. Owing to lesser incidence of pest and disease in treatment non adoption of plant protection measures (T_3) from full package reduction in seed yield was less. Withdrawal of fertilizer and weeding from whole package (T_6) induced substantial decline in seed yield (475 kg/ha) in comparison with removal of fertilizer and plant protection measures from total package, T_5 (526 kg/ha), highlighting the importance of weeding and fertilizer management in castor. The oil % of castor seed measured from the primary spike yield was not much influenced by withdrawal of different components of production from whole package.

Table 1 Growth and yield attributes as influenced by resource constraints in rainfed castor

Treatment	Plant height up to primary raceme (cm)	Number of spikes/plant	Length of primary spike (cm)	Number of capsules/spike	100 seed weight (g)
T_1: Full Package	37.6	8	31.2	35	27.2
T_2: T_1- Fertilizer	31.9	7	27.0	30	25.1
T_3: T_1- Plant protection	39.1	7	30.5	27	27.0
T_4: T_1- Weeding	30.0	7	27.7	25	22.7
T_5: T_1- (Fertilizer + plant protection)	34.4	7	27.9	22	25.1
T_6: T_1- (Fertilizer + weeding)	30.9	5	23.9	23	23.2
T_7: T_1- (Plant protection + weeding)	33.8	7	24.1	19	24.3
T_8: T_1- (Plant protection + fertilizer + weeding)	31.3	5	27.5	18	20.9
SEm+-	2.7	1.1	1.6	2.1	1.6
CD (P=0.05)	8.2	3.2	10.1	6.5	5.0

Table 2 Economics of castor as influenced by resource constraints

Treatment	Seed yield (kg/ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
T_1: Full Package	1170	26775	14625	2.2
T_2: T_1- Fertilizer	660	14850	4700	1.5
T_3: T_1- Plant protection	737	16583	5253	1.5
T_4: T_1- Weeding	514	11565	2335	1.3
T_5: T_1- (Fertilizer + plant protection)	526	11835	2405	1.3
T_6: T_1- (Fertilizer + weeding)	383	10688	2278	1.3
T_7: T_1- (Plant protection + weeding)	475	8618	1288	1.2
T_8: T_1- (Plant protection + fertilizer + weeding)	284	6390	-120	-0.98

Economic analysis revealed that adoption of full package accrued greater monetary benefits (net returns and B:C ratio of ₹14625/ha and 2.2, respectively) (Table 2). Non-adoption of weeding, fertilizer and plant protection measures individually from the whole package reduced the net returns by ₹ 2335/ha, ₹ 4700/ha and ₹ 5253/ha, respectively. Thus, non-adoption of weeding and fertilizer either alone or in conjunction depressed net returns to greater extent. Non-adoption of plant protection, weeding and fertilizer in conjunction made the crop non remunerative (₹-120/ha).

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Prospects of micro-irrigation in castor, *Ricinus communis* L.

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Abstract

Castor is a drought tolerant plant well adapted to low moisture conditions by deep rooting and having reflector bloom on stem and leaves to reduce heat load and thrive under conserved moisture. Newly released varieties and hybrids of castor respond well to irrigation. The research work on scheduling of irrigation is reviewed both in rainfed and irrigated ecosystem. The use of micro irrigation is rapidly increasing in the country, and it is expected to continue to be a viable irrigation method for castor production. The prospects and potential of micro irrigation with focus on drip system, fertigation and sprinkler system of irrigation is discussed in the present paper.

Keywords: Micro irrigation, castor, drip system, fertigation, sprinkler

Introduction

Castor (*Ricinus communis* L) is one of the important non-edible oil seeds having immense industrial and medicinal value and India is the major producer of castor. Castor is a hardy perennial plant well adapted to semi-tropical environment and grown on a wide range of climatic conditions throughout warm-temperate and tropical regions. It is a drought tolerant plant well adapted to low moisture conditions by deep rooting and having reflector bloom on stem and leaves to reduce heat load and thrive under conserved moisture. Higher yields of castor can be realized with a moderate rainfall of 600-700 mm and fairly good yields have been obtained with a well distributed rainfall of 375-500 mm. In India, except in the state of Gujarat, large areas of castor cultivation is restricted to drylands. Thus, adoption of efficient soil and moisture conservation practices can result in higher castor yields for the same amount of rainfall.

It was established that the requirements of rainfall for castor during different periods of growth are not uniform. Excess rainfall in the first half of vegetation and during late autumn is harmful as it leads to quick vegetative growth, harming the reproductive growth (Moshkin 1986). Cyclonic showers in Andhra Pradesh in September-November when the rainy season sown castor is in flowering and capsule formation stages, completely devastates the crop due to occurrence of *Botrytis* disease. However, the late-sown crop in August-September escapes *Botrytis* and benefit of this cyclonic storm.

Scheduling of irrigation

Scheduling irrigation in terms of when, how and how much to irrigate is important to enhance productivity both under irrigated and limited irrigation conditions. The influence of irrigation at different stages of crop growth on the yield of castor was studied at Raichur and it was observed that irrigation between 95 and 155 days after sowing (DAS) recorded higher yields (1793 kg/ha), followed by irrigation at 55 days (1694 kg/ha) and between 55 and 155 days (1664 kg/ha) (DOR, 1993). Subba Reddy *et al.* (1996) reported that supplemental irrigation of 50 mm either at early (0-45 DAS) or mid (45-90 DAS) stress period gave 26% additional castor yield. The periods of vegetative, primary and secondary spike developmental stages were found to be the critical stages for moisture. Soil mulch through interculture at early stress period gave 8% higher yield over rainfed crop. Management practices imposed at mid stress period resulted in higher production of secondary spikes. The research work carried out on castor irrigation was reviewed by Ragahvaiah *et al.* (2006). At Mandore, under assured irrigated situations, application of 5 irrigations commencing at 75 days after sowing and there after at an interval of 25 days was found optimum. Under limited irrigated (2 irrigation) conditions of S.K. Nagar planting castor at a spacing of 60 cm x 60 cm ensured higher yield. In the light soils of North Gujarat, 5 to 8 irrigations to GAUCH-I hybrid depending upon monsoon at an interval of about 20 days commencing from 55 DAS was found beneficial. GCH-4 hybrid should be given 8 irrigations each of 50 mm depth at an IW/CP ratio of 0.80 to have the maximum cost: benefit ratio of 1: 11.64. Of the eight irrigations, 4 should be applied at 15 days interval after cessation of monsoon and the remaining four irrigations at an interval of 20 days (Dec. - Feb.). In North Gujarat, irrigating castor crop 14 times each of about 20-25 mm depth was found economical and resulted in net profit of ₹ 9975/ha. Though organic or plastic mulch was found to increase yield, their use is currently uneconomical.

Irrigation management

The irrigation of castor especially the dwarf hybrids, requires considerable skill to obtain maximum yields. The plant is extremely sensitive to excess soil water at all stages of growth. In areas where there are common high winds in dry season, the crop is more liable to uprooting. Standing water also increased the fungal infections, especially if it is in contact with the stem at a soil level. Young seedlings are very susceptible to various collar rots, and pre-planting water applications are to be preferred to immediate post emergence application.

Castor being a deep rooted crop can extract water from considerable depth in the soil. Individual irrigation may thus be relatively large and therefore less frequent irrigations, a subsequent reduction in transit losses. Where the length of the growing period is limited, initiate the onset of flowering by creating a slight water stress in the plant may be desirable. Irrigation should cease some three to four weeks prior to harvest. Varieties, which remain dwarf in habit when grown as rainfed may grow luxuriantly under irrigation, take longer time to mature and flower over on extended period. To check the growth, by withholding water for a short period prior to flowering, can reduce the vegetative phase and induce more rapid and even flowering in these types.

The number and intensity of irrigations depend on specific soils, their water holding capacity and the crop season in question. As compared to heavy soils, light textured soils require more frequent irrigations. Rainy season crop is usually grown as rainfed crop. The crop growth and yields are satisfactory if the onset of rainfall and its amount and distribution over the crop period is normal. However, if the crop is exposed to prolonged drought during reproductive phase, one or two supplemental irrigations either at primary spike development or secondary spike initiation will help in enhancing the yields. The rainy season crop should be protected from excess moisture during periods of heavy and continuous rains particularly in heavy soils by providing surface drainage, to drain out excess moisture from seed bed. During winter season the number of irrigations may go upto 6-8 while in summer as many as 12-15 irrigations are required at an interval of 7-10 days depending on soil type and prevailing weather conditions.

The first irrigation is given as pre or post sowing irrigation to ensure better germination, emergence and stand establishment, and this irrigation is given so as to bring the top 90 cm, soil layer to field capacity. The second irrigation is generally given at 3-4 leaf stage, the third at 6-8 leaf stage. The subsequent irrigations are given with 15-20 days interval depending on soil and climatic conditions. The most critical period for moisture is the terminal bud initiation to full flowering of primary spike. Hence, at this stage adequate moisture in seed bed should be ensured by proper scheduling of irrigation. The consumptive use in medium red loam soils of Telangana region is 500 mm. Furrow irrigation system is ideal for castor sown in ridge and furrow type of seed bed, as this system is the simplest system and also highly efficient, especially under undulated lands or undeveloped topography.

Potential of micro-irrigation

The use of micro-irrigation is rapidly increasing in the country, and it is expected to continue to be a viable irrigation method for agricultural production in near future even in crops like castor. With increasing demands on limited water resources and the need to minimize environmental consequences of irrigation, micro-irrigation technology will undoubtedly play an important role in the future. Micro irrigation provides many unique agronomic and water and energy conservation benefits that address many of the challenges facing irrigated agriculture today and in future.

Micro-irrigation has the potential for precise, high level management and is an extremely flexible irrigation method to design. It can be adapted to almost any cropping situation and climatic zone. Micro-irrigation can be used over a wide range of terrain conditions, and it has allowed expansion of irrigated crop production into areas with problems soils (either very low or very high water infiltration rates) and poor water quality that could not be used with other irrigation methods. It can be installed as either a surface or subsurface water application system.

Drip irrigation in castor

Drip irrigation is defined as the precise, slow application of water in the form of discrete or continuous or tiny streams of miniature sprays through mechanical devices called emitters or applicators located at selected points along water delivery lines. It is also called trickle irrigation. Patel *et al.* (1998) studied the effect of drip irrigation at Khanda (Gujarat) on GCH-4 castor (0.2, 0.4, 0.6, and 0.8 of Cumulative Pan Evaporation, CPE) and observed that drip irrigation gave significantly higher yield than surface irrigation, with no difference between rates. Water use efficiency was higher with drip irrigation than surface irrigation and it increased with decreasing rate. In North Gujarat, adoption of drip irrigation to GCH-4 hybrid was found to save 24% water and gave 36% higher seed yield. The drip system should be laid out at a lateral spacing of 90 cm and dripper spacing of 60 cm and operated at a pressure of 1.2 kg/cm^2 using 4 LPH dripper. During the months of November-December, the system should be operated for 41 minutes, while from December -February for 35 minutes and from March- April for 65 minutes. Under limiting water supply, the system should be operated for 38 minutes during September-November; 30 minutes from December - February and 43 minutes from March - April. Malavia *et al.* (1995) found that drip irrigation at 0.3-0.9 CPE was superior to surface irrigation. Economic feasibility of drip irrigation was assessed on castor bean hybrid GCH 4 grown on sandy loam soils. The treatments comprised 0.4, 0.6 and 0.8 fraction of pan evaporation (FPE, through drip) and surface method of irrigation (control). Pooled analysis of data showed that the highest seed yield (2635 kg/ha) was obtained under irrigation at 0.8 FPE. In addition, an extra income of ₹ 2280/ha was obtained under irrigation at 0.8 FPE. The highest % of water saved, water expense efficiency and additional irrigated area compared to the control was 62.3, 8.36 kg/ha/mm, and 1.65 ha, respectively.

Fertigation in castor

Fertigation through micro irrigation systems is very effective in both arid and humid areas where nutrients and other salts are leached to the perimeter of the wetted zone. Thus, crops almost always respond well to fertigation with micro irrigation systems, especially on sandy soils with low cation exchange capacities. Fertilizer applied by conventional methods may be unavailable to micro irrigated crops in arid areas unless it is placed within the irrigated zone.

The potentiality of drip system for irrigation and fertigation in rainy season grown castor was evaluated at Junagadh, Gujarat. The results revealed that drip irrigation scheduled at 0.6 CPE and fertigation of 100% dose of nitrogen significantly increased seed and stalk yield with remarkably higher water use efficiency and net returns as compared to surface irrigation and soil application of nitrogen (Lakkad *et al.*, 2005). In North Gujarat, following drip irrigation system and 150 kg N/ha as fertigation resulted in 17 % higher income (30 kg N/ha applied as basal and the rest 120 kg N in splits at monthly interval). Application of 60 kg N/ha as fertigation did not reduce the yield. In S.K.Nagar, Gujarat, fertigation studies on castor indicated that application of 40 kg N/ha through drip gave comparable seed yield to that of 100 kg N/ha by soil application. This may be due to better utilization of N owing to good development of root system of castor crop. Fertigation, thus increased the fertilizer use efficiency as compared to normal application of fertilizers to soil (Patel *et al.*, 2006).

Sprinkler system

Sprinkler irrigation system conveys water from the source through pipes under pressure to the field and distributes over the field in the form of spray of 'rain like' droplets. It is also known as over head irrigation. Malavia *et al.* (1995) found that sprinkler system was cost effective in castor than drip system in Gujarat. The major limitation of crop with *Botrytis* gray rot is threatening crop's continuance in Andhra Pradesh. One of the alternatives to avoid this threat is castor cultivation during winter season. To avoid the complete crop loss, farmers in traditional castor growing areas of Andhra Pradesh (Mahaboobnagr, Nalgonda, Ranga Reddy districts) are taking up the crop in winter with sprinkler system of irrigation. Use of sprinklers lead to change in the micro-climate and the resultant high humidity might increase the pest-disease complex which needs further research. Similarly, the timing of sprinkler use is important as the pollen might get washed away and adversely affect when used in seed production plots, which needs in-depth investigations.

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Contribution of upper leaves to seed yield of castor

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Abstract

Contribution of upper leaves to seed yield was studied in castor during rainy season of 2008 at DOR, Hyderabad by imposing defoliation @ 0, 25, and 50% from top on primary secondary and tertiary branches at different spike initiation stages separately and also in combination. With defoliation there was no significant reduction in total dry matter whereas primary seed yield decreased with 25 or 50% defoliation on primary either alone or in combination with other defoliation stages. Secondary seed yield reduced significantly with 50% defoliation only on secondaries. Defoliation has no significant effect on tertiary seed yield. 25 and 50% defoliation on all order branches reduced seed yield of all branches and with significant reduction only in primary and secondary but not in tertiary seed yield.

Keywords: Defoliation, upper leaves, yield, castor

Introduction

Castor is indeterminate in growth habit and in such species competition for assimilates is common as both vegetative and reproductive growth continue simultaneously. In this crop, the next order branches are produced in the leaf axils basipetally resulting in severe competition for assimilates as the same leaf has to support both spike and branch growth. Thus, removal of upper leaves affect the yield of that order and growth of next order branch. Defoliation decreases yield by reduced light interception, reduction of plant photosynthesis, reduction of stored dry matter caused by leaf area loss and reduction of the filling period (Board *et al.*, 1994). The leaves nearer to the capsules contribute more to their filling (Shaifullah *et al.*, 2000) and therefore, defoliation of upper leaves reduced yields in castor (Ramesh and Prasad, 2001), sunflower (Sabri and Hasan, 2007), okra (Iremiren, 1987). Whether castor can recover from leaf loss because of its indeterminate nature or some yield loss is imminent because of competition is not clear. Therefore, to know the contribution of upper leaves to yield of that order and to next higher or lower order, an experiment was conducted during rainy season of 2008 with defoliation of upper leaves at different growth stages.

Materials and methods

Castor (cv. 48-1) crop was raised in randomized block design with 3 replications during rainy season of 2008 at Narkhoda farm of Directorate of Oilseeds Research, Hyderabad with recommended spacing and fertilizers. 3 levels of defoliation i.e., 0, 25, and 50%, were imposed at spike initiation stage on primary, secondary and tertiary branches separately and in combination. Defoliation treatments were imposed by removing upper leaves on primary, secondary and tertiary at 59, 73 and 94 days after sowing respectively. Data on removed leaf number and area, growth, dry matter, yield components and yield of different order branches was recorded.

Results and discussion

Removed leaf number, area and dry weight were quantified at each stage of defoliation. As leaf number was used as criterion to impose treatments, the actual defoliation was not exactly 25 and 50% in those treatments and the actual leaf area removed (%), plant height, length of different branches and total dry matter (TDM) were presented in table 1. Defoliation did not influence branch number and stem girth (data not presented). Plant height increased significantly with 25 or 50% defoliation on primary along with secondary and also with 25% on primary plus tertiary branches. Secondary branch length increased significantly with 25% defoliation on tertiary whereas 50% defoliation on primary significantly increased tertiary branch length. This clearly shows that defoliation on one order influenced the growth of other order branches. With defoliation at any stage and also with increase in % defoliation there was no significant reduction in TDM.

Data on yield components and yield of different order branches was presented in table 2. Primary seed yield decreases with defoliation of top 25 or 50% leaves on primary either alone or in combination with other order branches because of reduced capsule number and dry weight of primaries. Higher order branches compensated for the loss in primary seed yield with defoliation only at primary spike initiation stage. Capsule number and dry weight on secondaries reduced significantly with 50% defoliation on secondary either alone or in combination. Capsule dry weight also decreased with 50% defoliation on both primary and tertiary and with any amount of defoliation on all order branches. Seed yield decreased significantly with 50% defoliation (actual area removed was only 10%) on secondary either alone or in combination. With less than 10% leaf area removal (actual leaf area removed at 25% was only 7%) there was no effect on secondary seed yield. With 50% defoliation on primary and secondary (actual defoliation is 69, 25% respectively) and on secondary and tertiary (actual defoliation is 22, 13% respectively), secondary seed yield reduced significantly. Tertiary capsule number, weight and seed yield were not affected due to defoliation on tertiary either alone or in combination with other order branches. 25% (actual defoliation is 14+8+4% respectively) and also 50% (actual defoliation is 42+14+9% respectively) defoliation on primary + secondary + tertiary branches reduced seed yield of all order branches with significant reduction only in primary and secondary seed yield.

Total seed yield reduced significantly only with defoliation on all order branches either at 25 or 50% . When defoliation was imposed only on primary, plant tried to compensate by producing more seed yield on secondary and tertiary branches compared to control (Table 3). Similarly, primary and tertiaries tried to compensate the yield reduction due to defoliation only on secondaries. Where as secondaries compensated for tertiary spike yield loss only up to 25%, beyond that even secondary seed yield was also reduced along with tertiaries. Thus, plants try to compensate loss in the early stages with growth in higher order branches. There was >10% reduction in seed yield with 50% defoliation either alone or in combination except for 50% defoliation on primary. Thus 25% leaf removal (7-31%) even from the top at any one or two stages do not result in yield loss. Even our earlier studies support this (Lakshmamma *et al.*, 2009). But removal from all order branches (even 25%) results in significant yield reduction. In another study with castor it was found that the tolerance limit for defoliation was 25% (Dinesh and Sundaramoorthy, 2002) whereas in sunflower removal of top 5 fully expanded leaves significantly reduced yield (Sabri and Hasan, 2007).

From this study it can be concluded that castor can compensate for leaf loss upto 25% at one or two stages by increasing growth of other branches.

Table 1 Per cent leaf area removed and growth of castor (cv. 48-1)

Treatment	% Leaf area removed			Plant height	Mean length of branches (cm)		Total drymatter
	Primary (P)	Secondary (S)	Tertiary (T)	(cm)	Secondary	Tertiary	(g/plant)
25%P	18	0	0	105	31	16	253
50%P	44	0	0	106	30	20	228
25%P+S	26	14	0	129	38	14	245
50%P+S	69	28	0	137	33	14	261
25%P+T	31	0	9	128	39	15	276
50%P+T	47	0	7	104	26	17	208
25%P+S+T	14	8	4	109	29	12	221
50%P+S+T	42	14	9	113	24	13	203
25%S	0	7	0	115	29	12	277
50%S	0	10	0	102	32	18	260
25%S+T	0	9	9	111	32	19	280
50%S+T	0	22	13	116	37	12	264
25%T	0	0	11	118	42	16	260
50%T	0	0	19	111	39	14	262
Control	0	0	0	104	31	15	258
Mean				115	336	15	254
SEm±				7.4	2.8	1.7	19.8
CD (P=0.05)				21	8	5	57

Table 2 **Capsule number, weight and seed yield of different spike orders (g/plant) of castor (cv. 48-1)**

Treatment	Primary (P)			Secondary (S)			Tertiary (T)		
	Capsule number	Capsule weight (g/plant)	Seed yield (g/plant)	Capsule number	Capsule weight (g/plant)	Seed yield (g/plant)	Capsule number	Capsule weight (g/plant)	Seed yield (g/plant)
25%P	38	38.2	24.8	20	63.5	43.5	15	63.9	41.7
50%P	23	18.8	14.1	20	65.7	40.5	15	61.6	44.7
25%P+S	40	38.4	26.5	18	59.2	32.8	12	49.8	37.2
50%P+S	25	25.6	18.4	15	47.9	29.6	15	70.0	43.4
25%P+T	40	40.1	24.3	21	68.1	43.7	14	62.7	35.6
50%P+T	24	20.8	13.6	18	47.1	34.8	14	57.6	33.4
25%P+S+T	37	33.6	22.0	18	44.1	28.8	13	47.4	30.3
50%P+S+T	24	23.7	15.4	14	36.8	26.5	15	53.1	30.1
25%S	45	53.8	34.8	21	57.6	31.8	15	62.3	33.5
50%S	39	46.1	31.5	16	45.7	28.9	17	61.1	37.8
25%S+T	43	48.8	33.3	21	60.3	35.7	16	69.1	40.0
50%S+T	49	54.9	34.1	16	58.0	25.7	12	48.1	28.3
25%T	52	52.8	32.2	23	71.1	41.5	13	49.8	28.3
50%T	49	54.7	31.4	20	55.5	32.9	12	42.5	26.9
control	53	50.5	32.2	20	62.0	37.0	16	53.8	32.6
Mean	39	40.0	26.4	19	56.2	34.2	14	56.8	34.9
SEm±	3.68	3.59	2.33	1.24	5.40	3.03	1	9.0	3.5
CD(P=0.05)	10.7	10.4	6.8	4	15.8	8.8	NS	NS	10.0

Table 3 Total seed yield and per cent reduction in castor (cv. 48-1) seed yield

Treatment	Total seed yield (g/plant)	% reduction in seed yield			
		Primary (P)	Secondary (S)	Tertiary (T)	Total
25%P	110.0	23	-18	-28	-8
50%P	99.4	56	-10	-37	2
25%P+S	96.5	18	11	-14	5
50%P+S	91.4	43	20	-33	10
25%P+T	103.5	25	-18	-9	-2
50%P+T	81.5	58	6	-3	20
25%P+S+T	81.1	32	22	7	20
50%P+S+T	72.0	52	28	8	29
25%S	100.1	-8	14	-3	2
50%S	98.3	2	22	-16	3
25%S+T	109.0	-4	4	-23	-7
50%S+T	88.1	-6	31	13	14
25%T	109.7	0	-14	14	0
50%T	91.1	3	11	18	11
control	101.8				
Mean	95.6	19	8	- 8	7
SEm±	6.5				
CD(P=0.05)	18.9				

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Establishment of critical boron limits for castor, *Ricinus communis* L. in Alfisol

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Abstract

A field experiment was conducted in a red sandy loam (Alfisol) soil to establish boron critical limit in castor. Recently matured leaf (RML) samples positioned on the main stem from the top were collected at 65 and 90 days after sowing and analysed for boron content. Critical boron limits for castor (var. 48-1) leaves at 65 and 90 DAS were found to be 39 and 40 mg/kg respectively and the hot water soluble boron critical limits for Alfisol was 0.67 and 0.72 mg/kg, respectively.

Keywords: Castor, critical limit, boron, leaves, Alfisol

Introduction

Castor (*Ricinus communis* L.) is one of the important industrial oilseed crops cultivated in semi arid tracts of Telangana region of Andhra Pradesh under rainfed conditions in red *Chalka* soil (Alfisol). Amongst the seven micronutrients essential for crop growth and development, boron (B) plays vital role in oilseed production. The essentiality of B in oilseeds crops has been well established (Agarwala *et al.*, 1981). Further, in several oilseed growing areas of semi arid region deficiencies of B along with the other nutrients are wide spread (William Dar, 2004). Boron studies in major oilseed crops were recently reviewed by Murthy (2006). However, information regarding B studies in castor is scanty. Hence, an investigation was made to establish boron critical limit in castor grown in Alfisol.

Materials and methods

A field experiment was conducted with castor (variety: 48-1) as test crop during rainy season of 2009 to determine critical B level in red sandy loam (Alfisols) soil. Physico-chemical characteristics of the soil were pH 7.3, E.C. 0.24 dS/m, Organic carbon 0.31%, available N, P 186 kg/ha, 12 kg/ha respectively and exchangeable K i.e., 220 kg K_2O/ha. Hot water soluble boron content in the initial soil was low i.e. 0.32 mg/kg. Experimental design was randomised block with three replications. Graded levels of B *viz.* 0, 0.5, 1.0, 1.5, 2.0, 2.5 and 3 kg/ha supplied through Borax. Recommended dose of NP (40 kg/ha each) was applied. Recently matured leaf (RML) samples of the main stem from the top were collected at 65 and 90 days after sowing (DAS) and analysed for B content. Soil available B was estimated at initial and 30 days after the basal application of B, as per the standard procedures (Jackson 1973). Boron content in the leaves was estimated as per the procedure described by Wolf (1971). Scatter diagrams were drawn to establish soil and castor leaf critical B limits.

Results and discussion

Boron content in the recently matured leaves varied from 19.0 to 93.2 mg/kg at 65th day and 33.3 to 93.2 mg/kg at 90th day amongst the B treatments. In young leaf of mustard (52 DAS) the established deficiency, sufficiency and toxicity limits of B were 10-25, 25-70 and >70 mg/kg (Patel *et al.*, 2003). Sufficiency and toxicity levels of B for other oilseed crops like groundnut sunflower and soybean were 29-125 and 218, 29-125, 160 and 44, 63 mg/kg respectively (Sakal and Singh 1995). Earlier studies conducted by Murthy and Padmavathi (2009) showed that B content in the recently matured leaves of castor cv. 48-1 varied from 15.9 to 68.6 mg/kg at 65th day and 11.7 to 54.0 mg/kg at 90th day amongst the B treatments and the critical leaf B content at 65th and 90th day was 42 and 20 mg/kg, respectively. In the present investigation, the B content observed in the castor leaves corroborates the reported information in other oilseed crops. The scattered diagrams drawn for HWS-B vs. castor leaf B content at 65 and 90 days have shown that the critical leaf B content at 65th and 90th day was 39 (Fig.1) and 40 mg/kg, respectively.

Hot water soluble boron (HWS-B) content in the soil at 30th day varied widely from 0.60 to 0.91 mg/kg amongst the B treatments. Recently, Murthy and Padmavathi (2009) reported a critical HWS B content of 0. 71 mg/kg in red soil with castor cv. 48-1 as test crop. Low, medium and adequate critical levels of HWS-B reported for red and black clay soils of Tamil Nadu are <0.25, 0.25 to 0.50 and > 50 mg/kg, respectively (Patel *et al.*, 2003). Rattan and Goswami (2002) reported that oilseed crops grown soils may have critical limits of B in the range 0.1 to 1.0 mg/kg depending on the soil type and test crop. In this study, the critical limit of HWS-B content of the red soil (Alfisol) was found to be 0.67 mg/kg (Fig.1) at 65 DAS.

Present study showed that 0.67 mg/kg as the critical B concentration for the separation of boron responsive red sandy loam soil (Alfisol) from non responsive ones. Further, the critical castor leaf B content at 65th and 90th day was found to be 39 and 40 mg/kg, respectively.

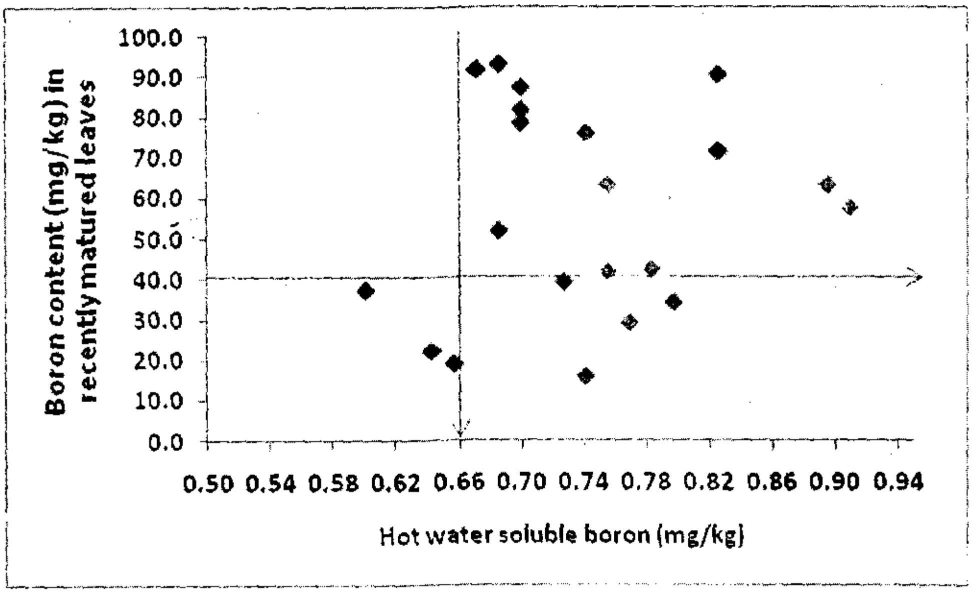

Fig. 1. Critical limits of boron in castor (cv. 48-1) leaves and in red soil (Alfisol)

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Comparison of soil test methods and potassium critical limit for castor, *Ricinus communis* L. genotypes in Alfisol

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Abstract

Field experiments were conducted with castor variety DCS-9 and hybrid DCH-32 during rainy season of 2004 in red sandy loam (Alfisol) soil under rainfed conditions to study the suitability of different soil test methods and establishment of various forms of critical limits of potassium (K) in soils. The quantities of K extracted by different extractants in soils varied widely from as low as 19.2 and 17.9 mg/kg (water extractable) to 922.1 and 926.8 mg/kg (boiling 1N HNO_3 extractable) when DCS-9 and DCH-32 castor genotypes were grown as test crops respectively. Critical K limit establishment by using soil K forms vs total seed yield of castor data revealed that, square root technique is comparatively better as showed by the high correlation coefficient values. Various forms of critical K limits were also established with castor variety DCS-9 and hybrid DCH-32.

Keywords: Castor, soil test, potassium, critical limit

Introduction

Castor (*Ricinus communis* L.) is an industrial crop grown in different soil types in India. Castor crop response to nitrogen (N) and phosphorus (P) fertilization is well known. Potassium (K), one of the macro key nutrients for improving the crop yield is often neglected by the farmers assuming that it is adequately available in the soil. However, intensive cropping systems and continuous use of NP fertilizers alone led to the deficiency of K in soil. A castor crop yielding 10 q/ha under rainfed conditions removes 40 kg N, 9 kg P_2O_5 and 16 kg K/ha as against 84 kg N, 26 kg P and 31 kg K/ha removed by a crop of 22.8 q/ha under irrigated conditions (Raghavaiah 2005). Castor crop response to K fertilization is reported by various researchers (Dinesh Hans and Sundaramoorthy, 2004; Murthy and Muralidharudu, 2003; Reddy and Reddy, 2005; Reddy *et al.*, 2005). Soil analysis is a valuable tool for diagnosis of K deficiency in soils and particularly in plants. Several chemical methods for determining plant available K has been evolved but their suitability varied with soil characteristics. Critical limits of K in soil and plant differ in relation to variation in extraction capacities of different extractants and crop characteristics. The present field investigation is aimed at studying the suitability of different soil test methods and establishment of critical limits of K in soils with castor as a test crop.

Materials and methods

Two separate field experiments were conducted with castor variety DCS-9 and hybrid DCH-32 during rainy season of 2004 in red sandy loam (Alfisol) soil under rainfed conditions. Physico-chemical properties of the experimental soil were pH 7.5, E.C. 0.11 d/Sm, Org. C. 2.6 g/kg, CEC 9.5 c mol (p^+)/kg, available N, P_2O_5 and K_2O 180, 12 and 204 kg/ha, respectively. Seven levels of K ranging from 0 to 120 kg K_2O/ha were applied through MOP and recommended dose of N: P_2O_5 (60:40 kg/ha, respectively) was applied the soil in which both the castor genotypes were grown. Soil samples were collected at 45th day and different forms of K were extracted as per the soil: extractant ratio and shaking time/reaction period stated in the table 1. Potassium content in the extractants were analysed by using flamephotometer. For the calibration of soil test methods, the correlation coefficients between K extracted by different extractants and relative % castor seed yield were worked out. Critical limits of K in soils were established by employing quadratic, square root, linear plateau and scatter diagram techniques. Cumulative seed yield of castor was recorded.

Results and discussion

Seed yield of castor cv. DCS-9 and DCH-32 was significantly influenced by K fertilization and varied from 852 to 1304 and 871 to 1302 kg/ha respectively. The quantities of K extracted by different extractants in experimental soils varied widely from as low as 19.2 and 17.9 mg/kg (water extractable) to 922.1 and 926.8 mg/kg (boiling 1N HNO_3 extractable) when DCS-9 and DCH-32 castor genotypes were grown as test crops respectively (Table 1). Based on the mean extractable K contents of the soil in which DCS-9 was grown different extractants can be arranged in the descending order as boiling 1N HNO_3 > 1.38N H_2SO_4 > 0.01M $CaCl_2$ > 3N HCl > 0.5M $NaHCO_3$ > 1N NH_4OAc > 0.75N HCl > 0.01$BaCl_2$ > 0.01M Citric acid > water. Whereas, different K extracts of the soil in which DCH-32 was grown followed the descending order as boiling 1N HNO_3 > 0.01M $CaCl_2$ > 1.38N H_2SO_4 > 3N HCl > 0.5M $NaHCO_3$ > 1N NH_4OAc > 0.75N HCl > 0.01M Citric acid > 0.01$BaCl_2$ > water. The amount of K extracted by boiling 1N HNO_3 was highest because this extract desorbs non-exchangeable K (reserve K) in addition to the water soluble and exchangeable quantities. The average amount of K extract with 1N NH_4OAc (pH7) was higher than that with 0.75 N HCl, water and 0.01M $CaCl_2$ possibly because of their relatively comparable ionic radii.

Various analytical procedures under investigation were calibrated by establishing the relationships of extractable K with relative % seed yield. The coefficient of correlation were generally higher with 1N HNO_3, 1N NH_4OAC (pH 7) and other extractants. As the degree of coefficient of correlation between the quantities of K extracted by boiling 1N HNO_3 and 1N

NH_4OAc and yield were high (>0.80**) those extractants could be considered suitable for determining available soil K. Further boiling 1N HNO_3 exhibited highest degree of correlation with the yield showing its superiority over 1N NH_4OAc. The correlation data suggest that 1N NH_4OAc extraction method, which estimates mostly the readily available fraction of soil K (water soluble + exchangeable) correlated significantly with the castor seed yield. It can give a fair index of available K while boiling 1N HNO_3 which estimates appreciable amount of non-exchangeable (reserve K) may provide a better prediction for plant available K. Under green house conditions in K deficient Alfisols, a critical 1N NH_4OAc extractable K limit of 225 kg/ha was reported earlier by Murthy and Muralidharudu (2003).

In view of the high degree of correlation (>0.80**) of the soil test values, obtained with 1N HNO_3, 1N NH_4OAc and other extractants with relative % seed yield, critical limits of the K extracted by these extractants were established by employing quadratic, square root, linear plateau and scatter diagram techniques for the soils in which the castor genotypes were grown (Table 2). Critical K limits varied not only with different K extractants but also with different techniques used for both the castor genotypes (Table 2).

Various forms of critical K limits were established with castor variety DCS-9 and hybrid DCH-32 as test crops. Critical K limit establishment by using soil K forms vs total seed yield of castor data revealed that, square root technique is comparatively better as evidenced by the high correlation coefficient values. However, validation of various forms of critical K limits in farmers' field under similar soil conditions with castor as a test crop is imperative.

Table 1 Quantities of extractable K (mg/kg) by different extractants in the experimental soil in which castor genotypes DCS-9 and DCH-32 were grown

Extractant	Soil extractant ratio	Shaking time/reaction period (min.)	DCS-9	DCH-32
			Range (mg/kg)	Range (mg/kg)
1N NH_4OAC	1:5	5	102.5-291.2 (153.7)	99.7-248.4 (163.3)
0.5M $NaHCO_3$	1:20	30	152.7-358.8 (205.6)	138.7-340.1 (208.9)
Water	1:10	30	19.2-65.2 (38.7)	17.9-52.9 (35.8)
0.01M $CaCl_2$	1:10	30	194.7-417.5 (268.5)	197.0-502.4 (302.9)
0.01N $BaCl_2$	1:10	30	60.6-173.5 (92.6)	45.2-170.7 (94.4)
0.75N HCl	1:10	30	70.4-161.8 (100.4)	73.7-173.2 (112.9)
3N HCl	1:10	30	191.7-394.7 (264.0)	179.9-364.6 (259.0)
1N HNO_3	1:10	Boiling for 10	391.0-922.1 (608.3)	472.9-926.8 (679.1)
1.38N H_2SO_4	1:26	Keeping for 30 minutes followed by leaching	73.8-832.5 (377.9)	33.9-636.3 (272.1)
0.01M Citric acid	1:10	30	69.4-98.0 (83.3)	67.4-181.7 (112.5)

Figures in parentheses are the mean values

Table 2 Critical potassium (mg/kg) limits established in red soil (Alfisol) by different extractants and methods for the castor genotypes DCS-9 and DCH-32

Extractant	Quadratic		Square root		Linear Plateau		Scatter diagram	
	DCS-9	DCH-32	DCS-9	DCH-32	DCS-9	DCH-32	DCS-9	DCH-32
1N NH_4OAC	223.9 (0.949)	230.3 (0.689)	217.0 (0.979)	227.8 (0.840)	93.2 (0.383)	96.5 (0.621)	153.7	163.3
0.5M $NaHCO_3$	283.4 (0.881)	297.3 (0.614)	275.0 (0.941)	325.5 (0.788)	136.6 (0.373)	138.3 (0.546)	205.6	208.9
Water	54.6 (0.973)	59.1 (0.708)	58.1 (0.972)	71.2 (0.839)	12.7 (0.749)	11.4 (0.660)	38.7	35.8
0.01M $CaCl_2$	340.6 (0.900)	427.5 (0.685)	337.6 (0.963)	424.2 (0.841)	148.8 (0.550)	143.3 (0.550)	268.5	302.9
0.01N $BaCl_2$	133.1 (0.962)	142.4 (0.712)	130.2 (0.982)	143.2 (0.863)	57.2 (0.403)	44.5 (0.607)	92.6	94.4
0.75N HCl	132.3 (0.959)	161.0 (0.656)	131.8 (0.975)	165.0 (0.818)	57.9 (0.495)	74.0 (0.603)	100.4	112.9
3N HCl	336.0 (0.982)	340.9 (0.902)	336.4 (0.991)	338.7 (0.952)	166.6 (0.601)	163.2 (0.730)	264.0	259.0
1N HNO_3	900.3 (0.950)	838.3 (0.843)	826.3 (0.962)	935.6 (0.922)	335.4 (0.682)	387.1 (0.732)	608.3	679.1
1.38N H_2SO_4	736.0 (0.971)	550.5 (0.715)	786.8 (0.961)	570.7 (0.886)	152.2 (0.698)	149.3 (0.626)	377.9	272.1
0.01M Citric acid	97.5 (0.961)	170.8 (0.619)	98.1 .(0.974)	173.9 (0.793)	66.4 (0.865)	69.0 (0.569)	83.3	112.5

Figures in parentheses are r^2 values

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Castor : A self-sustaining crop

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Abstract

Castor (*Ricinus communis* L.) is an important industrial oilseed crop with wide distribution and adaptability with many morphotypes. Being perenniating nature with deep root system and indeterminate growth habit can survive the harsh abiotic and biotic stresses. The waxy bloom, variations in capsule spines is implicated in certain pest and disease tolerance. Though monoecious, beside the genetic makeup, the sex expression and the proportion of male to female flowers varies according to weather conditions such as temperature, moisture stress, day length, nutrition, etc. The plant has wide plasticity for variations in spacing and geometry by adjustments in branching pattern and thus suitable for many intercropping systems. It has low nutrient and water requirement with high use efficiency. The higher source under wet conditions and the leaf fall contributes both as surface mulch during crop growth and as a source of manure. The excess foliate can be use for eri silk production. The non-edible seed and hardiness of the crop with high oil yield potential, is the promising competing crop for biofuel programmes in waste lands and for adaptability to climate change. Thus castor is an efficient and resilient crop with many mechanisms for adaptability to wide production constraints and responds to management.

Keywords: Castor, drought tolerant, sex expression, cropping system, eri silk rearing, biofuel, climate change.

Castor (*Ricinus communis* L.) is a high value industrial crop, belonging to the Euphorbiaceae family. It is non-edible due to the presence of toxic protein 'ricin' in seed. The oil content in castor ranges from 48 to 55% out of which 90% is extracted. The castor oil is unique in terms of its dominance of a single fatty acid - ricinolic acid (90%) due to which all the special properties of oil and its uses are ascribed. About 94% of the produce is utilized for oil extraction and 6% is used for seed purposes. The castor plant, seed and oil have a number of uses. There are varied applications for castor oil and its derivatives that have widespread application in many industries like lubricant, paint, pharmaceutical, textiles, etc.

India is the global leader in castor production and castor oil trade holding a premier and dominant position in castor production and supplies. Owing to the vast industrial uses of castor oil and its derivatives, the demand continues to be high and India will continue to play a dominant role in the world castor seed production. The exports of castor oil are steadily rising from 4423 t valued at ₹.3.41 crores in 1981-82 to 596949 t valued at ₹.2253 crores in 2008-09 (Damodaram and Hegde, 2010).

Castor plant has several unique qualities that make it survive under extreme environments and revive after abiotic and biotic pressures. This paper briefly discusses the range of possibilities of castor's self sustenance that are distinctly superior over most cultivated crop plants.

Wide distribution

It has been regarded that the castor plant has a polyphyletic origin with four centres of variability. However, the Ethiopia, East African region is considered to be the most probable site of origin (Weiss, 1983). All types of castor have the same number of chromosomes ($2n = 20$). Chromosomal polymorphism is occasionally reported. In India, growing of castor and the use of its oil are so well established that its origin are lost in time and the theory of 'continental pairing' has been applied by some botanists to account for its ancient occurrence in India and the Ethiopian region. Thus the crop has universal adaptability. One can find castor everywhere in countryside, cityscapes, riverbeds, high altitude mountains, sea shores, marshy and arid ecosystems, etc., in all seasons. Many morphotypes of castor are found in wild that have unique traits of adaptation to the particular ecology *viz.*, variations in stem and leaf colour and pigmentation, bloom, branching habit, flowering, fruiting (capsule types), seed, etc., beside quality (Anjani and Jain, 2004). The typical adaptation environments also serve as source for particular trait of interest in targeted crop improvement. Castor is normally cross-pollinated, wind being the major agent in the tropics that makes it easier for successful pollination effortlessly, unlike pollination depending on any external agents.

Wide agro-climatic adaptability

Castor plant is well adapted to survive over many seasons by virtue of its perennial habit and deep rooting through which it can survive cycles of abiotic and biotic stresses. Castor requires a moderately high temperatures ranging from 20-26°C with low humidity and long, clear, sunny days throughout the growing period to produce maximum yields. However, it is acclimatized to different temperatures for survival. Hitherto, castor is known as a crop of rainy season extending up to summer depending on the duration and supporting moisture conditions. Now it is gaining popularity as winter crop with higher productivity potential. Thus, it proves that the crop can exploit better growing conditions to yield higher while under uncertain growth conditions (rainy season) it survives the stresses.

In India, castor is cultivated in shallow high sandy loams (<10% clay content) locally known as *Chalka* soils in Telangana region of Andhra Pradesh, to deep sandy loams of Gujarat. Relatively, among the other major factors of suitable climate, pest control and adequate nutrients, soil structure appears to be of secondary importance. The economic productivity of castor is better under mild stress conditions of moisture and fertility. Highly fertile soils favour excessive vegetative growth, prolong the period to maturity and greatly extend flowering. In subsistence farming, castor is often selected for growing in marginal lands which are generally not suitable for other crops. However, castor responds to good fertility and irrigation management.

Environment modified sex expression

Castor is a monoceous plant with both male and female flowers produced on the same inflorescence. Generally male flowers are at the bottom and female flowers distribute throughout the inflorescence above male flowers. Apart from the genetic makeup, the proportion of male and female flowers on the inflorescence vary due to the environmental influences such as temperature, day length, nutrition, irrigation or drought, etc., that are known to influence the hormonal regulation in developing male or female flowers (Shirfriss, 1961). In general, the harsher environment *viz.*, moisture stress, high temperature, low nutrition/fertility, and short day length increases male flowers and the opposite conditions favour production of female flowers (Hegde and Sudhakara Babu, 2002). The transition interspersed staminate flowers occur at the transition phase of these weather conditions. Thus the castor plant tides over the harsh weather by avoiding female flower production that would result in unsuccessful seed development. Whereas, under favourable cool temperature, wet/irrigated conditions, high soil fertility/nutrition, long days, etc., promote female flower production that has sure success of seed setting and development into mature ovule.

Drought tolerance

Castor is a drought tolerant plant well adapted to low moisture conditions by way of deep rooting and having reflector bloom on stem and leaves to reduce heat load and thrive under conserved moisture. Higher yields of castor can be realised with a moderate rainfall of 600-700 mm and fairly good yields have been obtained with a well distributed rainfall of 375-500 mm.

Castor is a deep rooted plant with its tap root extending beyond 2-3m under unrestricted conditions. In deep soils, it survives mostly on the soil moisture extracted from deeper layers and maintains its perennial nature. Castor plant modifies the root volume under drought to explore larger soil volume. The rooting pattern of castor genotypes under shallow Alfisols under rainfed condition indicate that under a moisture stress for 25 days during primary spike formation stage, for the same root length (restricted to shallow soil depth of 20-25 cm), the root volume increased by 10 folds while the root and plant dry weight increased marginally, a mechanism of drought tolerance of the crop (Sudhakara Babu, 2000).

The long duration of the annual castor crop makes full use of the growing season and moisture availability especially under bimodal rainfall pattern regions of Andhra Pradesh, Karnataka and Tamil Nadu wherein the rainy season from June-July to October months can not fit in double cropping while it is under utilized for a short duration crop.

The accelerated leaf fall under moisture stress is also a mechanism to reduce the transpiring leaf area to survive the stress by restricting its development and prolonging survival period. The leaf fall also serve as mulch to prevent evaporation of moisture from soil.

Perenniating nature

Castor is a hardy crop and can be cultivated in a wide range of agro-climatic conditions and soil types. An important distinguishing feature of castor is its perenniating nature. With the availability of adequate moisture, castor continues to give economic yields up to 8 to 10 years and can help to stabilize production even in fluctuating environments. Perennial castor trees of 8-10 years can be commonly found at backyards of many farmsteads that serve multiple uses from shade to stake.

Adaptability to cropping systems

Castor with its branching habit and wide plasticity for spacing to adjust the number of branches ideally suited for intercropping systems. In traditional areas, castor forms the base crop while in non-traditional areas it forms a component crop with the major crops of the region. Castor involving intercropping systems proved to be low risk and high stability due to the high resilience of castor for adaptation to biotic and abiotic stresses both under drought and excess rainfall seasons

(Sudhakara Babu, 1994). Short season crops like clusterbean or mungbean can be grown as additive series in the interspaces of wide spaced castor and harvested before the grand growth stage of castor (Sudhakara Babu and Padmaja, 2006). The residue can be usefully incorporated. In Gujarat, the popular groundnut + castor intercropping wherein castor is sown midway during the rainfed groundnut in rainy season (August end) and after harvesting of groundnut in October, castor is maintained under irrigation resulting in realizing highest yields of both the crops. Cowpea grown between the rows of castor and incorporated as green manure (10t/ha) around 45 days after sowing added 30 kg N/ha to the soil. Thus green leaf manuring is an alternate source of nitrogen with least cost (Subba Rao and Chandra Sekhara Rao, 1980). Castor is found to utilise the residual fertility effectively in succession with sunflower (Reddy and Sudhakara Babu, 1996).

Soil crust resistance

In majority of Alfisols, soil crust limits successful crop establishment. The germination of castor is epigeal and relatively less sensitive to soil crust problems due to its high strength to break the crust. Thus castor seeds are mixed as surrogate along with crust susceptible crops like sorghum, finger millet, sunflower, mustard, etc. (navadhnya mixed cropping in Alfisols in rainy season) so that when castor seedlings emerge breaking the crust, other crop's seedlings will also emerge out and establish themselves.

Wide plasticity for plant population and geometry

Castor is a branching and indeterminate plant with perenniating habit. Thus, for the same genotype, the spacing and plant population for optimum production varies with the growing conditions (Prasad and Sudhakara Babu, 1997). Owing to the branching nature, castor has a wide plasticity for adjustments in variation for spacing and plant population by adjustments in branching and yields/plant to give a normal yield/ha (Hanumantha Rao and Chakrabarty, 1997). Thus under delayed sowings, higher plant population is practiced to compensate the loss of branching and growth wherein the total number of spikes/ unit area is maintained.

It was established that the branching variety, under higher density, acquires a single spike with a uniform spread of the central spike with regard to height and is suitable of combine harvesting, whereas, a tendency towards an increase in yield from the lateral spikes was observed in very sparse plant stands (Moshkin, 1986).

Low nutrient requirement

It has been estimated that a 1.7 t/ha seed yield of castor removes the equivalent of 50 kg N, 20 kg P_2O_5 and 16 kg K apart from the nutrient removal through roots, stems and leaves (Hegde and Sudhakara Babu, 2002). This is much lower in comparative assessment especially with sunflower, mustard and soybean. There is no widespread deficiency of secondary and micronutrients noticed for castor (Weiss, 1983).

The senescing leaf fall of castor amounts to about 1 to 1.5 t/ha depending on growing conditions and genotype that serve as mulch to reduce soil moisture loss during the crop season and after the harvest of castor, it provides valuable nutrients to the succeeding crop. Thus even under no-external fertilizer applications, low to moderate castor yields were sustainably maintained over long periods but not devastated. Nor, the crops succeeding castor are adversely affected unlike crops like sunflower or maize. Castor does not have any allelopathic effect on succeeding crops establishment and productivity.

Adaptability to partial shade

The long gestation period of tree plantations in agro-forestry programmes can be profitably managed by intercropping with castor (Sudhakara Babu *et al.*, 1996). In marginal and sub-marginal lands, alley cropping of castor with subabul with use of lopped foliage of subabul as mulch gave an additional yield of 5.0q/ha (Singh *et al*, 1989). Bheemaiah *et al.* (1998) recorded favaourable physiological responses of castor under such alley cropping besides nutrient supplementation. Contrastingly, perennial tall castor types are popularly used as shade crops for cultivation of chillis, turmeric, ginger, etc. (Sudhakara Babu, 1994).

Low water requirement

Castor is a drought tolerant crop but responds favourably to irrigation. The water use efficiency of castor is high and results in very high return to investment on castor. Owing to its wide plasticity for plant geometry and population, it is much cheaper to adopt drip irrigation to 1.8m x 1.8m spaced castor and reap benefit over 2 to 3 years with multiple harvests (Hegde and Sudhakara Babu, 2002). Owing to wide spacing, adaptable for efficient surface methods of irrigation such as furrow or alternate furrow or basin irrigation instead of flood irrigation.

Pest tolerance

Castor has fewer pests and diseases limiting its production. The waxy coating bloom that confers drought tolerance is also implicated in conferring resistance to white flies and other sucking insect pests such as jassids or leaf hoppers than bloom-less types. Conversely, bloomless types were found to be more resistant to mites (Chandrasekharan *et al.*, 1964). The presence of toxic alkaloid 'ricinin' in leaves protect it against grazing from higher animals. Due to the perenniating habit with indeterminate plant type, there will be strong compensation for covering up the loss at earlier stages. Besides, the castor has high source size and defoliation of more than 50% has not caused significant yield losses (Weiss, 1983). Non-spiny capsule types are adapted to tolerate *Botrytis* infection without much yield loss compared to spiny capsule types.

Alternate opportunity at severe crisis

Botrytis gray rot incidence due to the inclement weather conditions that has attained a serious proportion in recent years in southern dry regions of Andhra Pradesh, Karnataka and Tamil Nadu causing total spike loss due to the molds in rainy season. The disease incidence is associated with the weather conditions at the time of flowering and early capsule development. The regular occurrence of cyclonic storms with cloudy weather at primary and secondary spike formation stages wherein the crop had attained maximum canopy causes high relative humidity in the microclimate with water drizzles retained in the bloom. This causes for incidence of the disease. Even after clearance of the cyclonic storms, the high moistness of the soil continues to provide favourable humidity for perpetuation of the disease resulting in total loss of spike (Hegde and Sudhakara Babu, 2002).

Under such severe endemic form of *Botrytis* occurrence and its effect to adversely affect the developing spikes, it brings possibility of compensation by virtue of higher soil moisture recharge and by top dressing with additional N after cyclonic storms promotes next order spikes and the loss in yield from early order spikes could be compensated. The available foliage on the *Botrytis* affected plants can be profitably utilized for eri-silk worm rearing. The new flush of leaves and spikes will emerge with the available soil moisture that can compensate for the loss.

Eri-silk worm

Castor has higher leaf area i.e 35 to 50% depending on the genotype and growing conditions. Green leaves are traditionally fed to 'eri silk worms' (Maiti *et al.*, 1988). Wet weather from vegetative growth stage promotes foliage production in excess of optimum requirement. Under such situation and at times of severe Botrytis incidence, the foliage up to 50% can be removed and used for rearing 'eri-silk worm' that gives additional income and employment opportunity besides promoting eri-silk industry.

Storage and seed viability

Castor beans are not affected by any storage pests due to the presence of hard seed coat and ricin toxin. Castor seed has long period of viability and can be safely stored for long periods (4 to 5 years) under normal room temperature and moist free conditions. Thus, castor seed can be easily stored under normal conditions anywhere under dry environment. Besides, castor beans are used effectively for safe storage of highly susceptible sesame seeds (Sudhakara Babu, 1994).

By-product utility

After oil extraction ricin rich castor cake is a valuable organic manure containing higher NPK that is especially used for high value crops like grapes, tobacco, vegetables, to protect from termites and nematodes. The castor stems after harvest serve as thatching and fencing material, fuel source besides as a source for furfurol and for energy generation through gasification.

Important candidate for biofuel programme

With restrictions on diversion of food crops for biofuel purpose, castor crop gains importance being a non-edible crop with high oil yield. Being a hardy crop to survive and grow under marginal and sub-marginal land, it is ideally suited for cultivation in waste lands that are earmarked for biofuel programme. The perennial nature of the crop can be suitably exploited under micro-irrigation to maintain a single planted crop for many years with multiple harvests. Castor stems have high calorific value and serve as source for making energy briquetts for generating energy. Castor forms a potential annual component for establishing energy plantations.

Adaptability to climate change

The unique quality of castor and its versatility to adapt and sustain many abiotic and biotic hurdles and survive with compensation makes it an efficient crop for perpetual cultivation under the threats of climate change. Being C_3 species, it is advantaged for future effects of global warming. Thus from each and every angle of sustainability *viz.*, wider agro-climatic adaptation, stable production, oil yield, pest tolerance, industrial and economic value, employment generation, conservation of resources, energy yield, pharmaceutical value, etc., castor scores high while most crops will succumb.

Thus, the popular belief that 'castor yields some (yield) where others yield none', is aptly describes its hardiness and resilience to withstand environmental stresses and resilience to perpetuate.

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Traits related to water use efficiency in castor, *Ricinus communis* L.

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Abstract

Under drought conditions, seed yield is determined by water use efficiency (WUE). This character showed significant genetic variability and heritability. Alternate approaches for measuring WUE are specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR), specific leaf nitrogen (SLN) and carbon isotope discrimination technique (CID). Pot (2002-03) and field experiments (2003-05) were conducted to estimate WUE, stage as well as position of leaf to be sampled and to relate them with other traits like SLA, SCMR, SLN etc. Total dry matter (TDM) and WUE showed positive relation with SCMR, SLN and negative relation with SLA and ^{13}C. These relationships are prominent at 55 DAS. Fourth fully expanded leaf from top on primary stem was identified as the index leaf to be sampled as good correlation was seen between different traits with this leaf.

Keywords: Castor, WUE, SCMR, SLA, SLN

Introduction

As there is only 1% of earth's water that is easily accessible, water deficits will continue to be the single most abiotic factor likely to affect crop yields globally. Under drought conditions, seed yield is determined by water use efficiency (WUE). This character showed significant genetic variability and also has heritability (Wright *et al.*, 1988). There are different approaches to identify drought resistant genotypes and traits related to WUE. They are gravimetry, gas exchange measurements and carbon isotope discrimination (CID) technique. Other alternate approaches for measuring WUE are measuring specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR) and relating it with specific leaf nitrogen (SLN) and mineral ash content etc. Relationships between SCMR with WUE, ^{13}C with WUE, ^{18}O with WUE, SLA and ^{13}C, SLA and WUE, TDM and WUE, SLN and WUE, etc., were established in groundnut besides, different crops. Establishing the relationships among all these characters and with WUE helps in identifying a simple, measurable and cost effective screening technique for drought tolerance as measuring WUE with gravimetry is very tedious and time consuming.

Although castor is grown in almost all the states, Gujarat and Andhra Pradesh account for major portion of the total area under the crop. However, the differences in the productivity levels of irrigated and rainfed conditions emphasize the need to re look into the strategies to be adopted for each situation separately. Castor cultivation under rainfed situations is limited due to erratic rainfall exposing the crop to periodic and intermittent droughts and reducing the productivity. Germination, establishment of crop stand and reproductive phases are critical stages for moisture stress under field conditions in castor crop. Limited attempts were made to identify genotypes that fare well under rainfed conditions. Hence, experiments were conducted to identify traits related to WUE in castor and establishing the relationships between different traits there by identifying a suitable screening technique for measuring WUE in castor, which can be used to identify genotypes that can perform better in drought conditions.

Materials and methods

A pot culture experiment was conducted during 2002-03, to estimate WUE by gravimetry. Four genotypes were studied in five replicates. Equal amount of soil is filled in each pot and were irrigated with equal measured quantity of water. Observations on SLA, SLN, SCMR and TDM were recorded at 20, 55 and 90 days after sowing (DAS). Water use efficiency (WUE) is calculated based on amount of water given and drymatter produced. To identify the leaf to be sampled for SLA measurement, observations on SLA, SLN and SCMR were taken on 1st, 2nd, 3rd and 4th fully expanded leaf from top on primary stem in DCH-177 at primary spike initiation stage.

Another field experiment was conducted during the winter season of 2003-05 to identify traits related to WUE in castor. Ten genotypes were sown in three replications and stress was imposed from 30-60 DAS. Observations were taken on 4th fully expanded leaf (FEL) from top at 55 DAS i.e., before relieving stress (BRS). The correlation coefficients among different traits were calculated and presented.

Results and discussion

Estimation of WUE by gravimetry (Pot culture): Observations on different traits were recorded at 20, 55 and 90 DAS. These relationships are strong at 55 DAS, hence data recorded at 55 DAS is only presented (Table1) as better correlations were seen at this stage. Correlation coefficients among different traits and with WUE were presented in table 2. Among the genotypes studied, GCH-4 recorded significantly more plant height, leaf area, TDM, and SCMR. Differences among genotypes for SLA, SLN and ^{13}C were not significant. GCH-4 recorded low ^{13}C and high WUE. Specific leaf area is used as alternate method for estimation of genetic variability for transpiration efficiency (TE) or water use efficiency (Wright *et al.*, 1988). Similarly SCMR is also a good estimate of leaf chlorophyll content and hence SLN as leaf N and chlorophyll are directly correlated. The relation between SCMR and TE was established by Sheshshayee *et al.*, (2001) in groundnut. SCMR showed negative relation with SLA, ^{13}C and positive relation with SLN and WUE, whereas, SLA showed negative relation with SCMR, SLN and WUE. SLN showed positive relation with WUE. ^{13}C and WUE were negatively correlated. Similar relationships were observed in groundnut by Nageswar Rao *et al.* (2001).

Identifying leaf position for SLA measurement (Field study): Leaf age and time of sampling influences SLA (Nageshwar Rao *et al.*, 1995). Different leaves were sampled on primary stem at primary spike initiation stage i.e., 40 DAS and observations were recorded. Correlation coefficients were calculated and presented in table 3. With increase in leaf position from top to bottom, SCMR, SLN increased. Differences in SLA were not significant. SCMR showed negative correlation with SLA, positive correlation with SLN and SLA showed negative relation with SCMR and SLN. Fourth fully expanded leaf from top showed strong negative relation between SCMR and SLA, SLA and SLN, SCMR and ^{13}C and strong positive relation between SCMR and SLN, SLA and ^{13}C, SLN and ^{13}C. So, ideal leaf to be sampled in castor for SLA measurement is 4th fully expanded leaf (FEL) from top on primary stem. Nageshwar Rao *et al.* (1995) identified 3rd or 4th leaf from top on main stem as index leaf to be sampled for groundnut.

Identifying traits for WUE: Traits like SCMR and SLA were recorded at 55 DAS (during stress) and at 90 DAS (before relieving stress) on 4th FEL during the winter season of 2003-04 and 2004-05 using ten genotypes. ^{13}C data was not estimated during 2003-04. SCMR increased with imposition of stress (Table 4). Though SLA decreased with stress, the result was not significant except during 2004-05. ^{13}C also decreased in stress. Among the genotypes, the response varied in different years. SCMR showed negative relation with SLA at 55 DAS in control (-0.38) and stress (-0.40) treatments in 2004-05 year. Genotypic differences are not similar with these traits in control and stress treatments though the overall response was similar hence not discussed. The TDM and seed yield was not affected due to stress in both the years as the stress was imposed only up to 60 DAS (data not presented) and the main emphasis was to identify traits related to WUE.

Thus, WUE showed positive relationship with SCMR, TDM and negative relation with SLA, ^{13}C. Where as SLA showed negative relation with SCMR and TDM. The relationship of ^{13}C with SLA and SCMR are not very clear. SCMR and SLA showed strong relation with WUE and these two traits can be measured easily hence can be used as surrogates for measuring WUE in castor. At primary spike initiation stage, 4th fully expanded leaf (index leaf) from top of primary stem should be sampled. Ideal stage for sampling to identify traits related to WUE in castor is secondary spike initiation stage.

Table 1 Growth, SCMR, SLA and SLN at 55 DAS in castor genotypes (Pot culture)

Genotype	Plant height (cm)	Leaf number	Leaf area (dm²)	TDM	WUE (g/litre)	SCMR	SLA	SLN	¹³C
DCS-9	25.2	6	4.0	1.7	0.17	45.3	3.94	4.44	19.96
PCS-4	28.8	6	4.66	2.1	0.20	47.7	3.37	4.38	20.02
DCH-177	26.1	6	5.28	2.1	0.20	46.1	4.05	4.54	19.83
GCH-4	32.9	6	7.13	3.0	0.28	50.5	3.63	4.97	19.74
Mean	28.2	6	5.27	2.227	0.21	47.4	3.75	4.58	19.89
CD(P=0.05)	2.5	NS	1.28	0.55		2.98	NS	NS	NS
CV (%)	13.7	8.3	25.7	26.25		4.94	11.28	6.97	

Table 2 Correlation coefficients among different traits at 55 DAs in castor (Pot culture)

Genotype	SCMR and SLA	SCMR and WUE	SCMR and SLN	SCMR and ¹³C	SLA and WUE	SLA and SLN	SLN and WUE	¹³C and WUE
DCS-9	-0.84	0.90	0.45	-0.31	-0.60	-0.63	0.31	-0.46
PCS-4	-0.79	0.78	0.83	0.49	-0.29	-0.96	0.35	0.42
DCH-177	-0.84	0.94	0.69	-0.80	-0.62	-0.34	0.84	-0.92
GCH-4	-0.87	0.44	0.99	-0.50	-0.58	-0.88	0.54	-0.06
Mean	-0.72	0.80	0.75	-0.24	-0.41	-0.44	0.63	-0.38

Table 3 SCMR, SLA, SLN and correlation coefficients in castor genotypes (Field study)

Leaf position	SCMR	SLA	SLN	¹³C	SCMR and SLA	SCMR and SLN	SCMR and ¹³C	SLA and SLN	SLA and ¹³C	SLN and ¹³C
1	43.1	1.99	3.58	20.84	0.20	0.32	0.77	0.08	-0.39	0.48
2	46.3	2.13	3.93	21.37	-0.23	0.17	0.02	0.36	-0.02	0.58
3	46.8	1.66	3.93	21.75	-0.61	0.47	-0.34	0.27	0.16	-0.11
4	47.6	1.80	4.18	22.14	-0.91	0.69	-0.87	-0.67	0.77	-0.40
Mean	46.0	1.90	3.91	21.53	-0.30	0.79	0.60	-0.11	-0.25	0.73
CD (P=0.05)	2.04	NS	0.22	0.13						
CV%	3.23	19.39	4.07							

Table 4 SCMR, SLA and ¹³C measurements before relieving stress (BRS)

Treatment	SCMR		SLA		¹³C
	2003-04	2004-05	2003-04	2004-05	2004-05
Control	48.3	52.0	2.014	2.009	-26.685
Stress	53.6	58.1	1.826	1.554	-25.344
Mean	50.9	55.1	1.920	1.782	-26.015
CD (P=0.05)	2.50	2.29	NS	0.046	1.84

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Inter-relay cropping of castor in pigeonpea under rainfed conditions

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Abstract

A field experiment was conducted on medium black soils during rainy seasons of 2008 and 2009 to study the effect of inter-relay cropping of castor in pigeonpea under rainfed conditions. Castor intercropped with pigeonepa (1:1) with simultaneous sowing recorded significantly higher yield of castor (763 kg/ha), number of spikes and primary spike length of castor than castor relay intercropped with pigeonpea staggered sowing at 15, 30 45 and 60 days after sowing (DAS) of pigeonpea. Simultaneous sowing of castor in pigeonpea gave higher castor equivalent yield (2077 kg/ha), compared to delayed sowing. Seed yield of castor decreased drastically with delay in sowing period. Economics of different treatments indicated higher B:C ratio (3.21) from both the crops of castor + pigeonpea seeded simultaneously.

Keywords: Castor, pigeonpea and relay cropping

Introduction

Castor is an important non edible oilseed crop of India which fetches sizeable amount of foreign exchange in the country through export. India's share in world's area and production of castor is 68 and 76%, respectively (Reddy *et al.*, 2006) It is ideally suited for intercropping system by virtue of its drought tolerance, perennial nature, branching habit and indeterminate phenology (Hegde and Sudhakara Babu, 2002). Being a long duration and widely spaced crop it offers a great scope for growing short duration intercrops like greegram, blackgram and other pulses, but because of the uncertain and erratic rainfall in the region, it is impossible to grow greengram and blackgram in castor. Since pigeonpea is a predominant pulse crop in the region, a study was conducted to know the influence of staggered sowing of castor in pigeonpea as intercrop.

Materials and methods

A field experiment was conducted during rainy season of 2008 and 2009 at Zonal Agricultural Research Station, Babbur Farm Hiriyur, Karnataka. The experimental soil was clayey in texture and slightly alkaline in reaction (8.0). The soil was medium in available nitrogen (286 kg/ha), available phosphorus (16 kg/ha) and high in available potassium (265 kg/ha). The organic carbon content was medium (0.5%). The experiment was laid out in randomized complete block design consisting of five treatments with four replications. Castor variety DCS -9 and pigeonpea variety BRG-2 were selected as test varieties. A recommend dose of fertilizers was applied to both the crops. Pigeonpea was sown at a row distance of 120 cm and castor was planted in between two rows of pigeonpea with an intra row spacing of 45 cm. Observations on yield components and yield have been recorded and B:C ratio and castor equivalent yield has been worked out.

Table 1 Yield components, yield, castor equivalent yield and B:C ratio as influenced by inter-relay cropping of castor in pigeonpea

Treatments	No. of spikes of castor/plant			Length of castor primary spike (cm)			Yield of castor (kg/ha)			Castor equivalent yield (kg/ha)			BCR
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	
Simultaneous sowing	7	7	7	33.7	32.8	33.2	800	725	763	2170	1984	2077	3.21
Sowing of castor 15 DAS of pigeonpea	5	4	5	28.7	26.8	27.8	623	578	601	1721	1752	1737	2.69
Sowing of castor 30 DAS of pigeonpea	4	3	4	22.5	20.8	21.7	502	426	464	1600	1624	1612	2.50
Sowing of castor 45 DAS of pigeonpea	2	2	2	14.0	12.3	13.2	199	145	172	1289	1347	1318	2.04
Sowing of castor 60 DAS of pigeonpea	2	2	2	8.7	6.8	7.8	101	82	92	1223	1354	1289	2.00
SEm +	0.48	0.7		0.61	1.10		246	16.8		78	97		
CD (P=0.05)	1.47	2.1		1.87	3.30		75.8	52.02		235	291		

DAS = Days after sowing

Results and discussion

Simultaneous sowing of castor + pigeonpea (1:1) recorded significantly more number of spikes (7 spikes/plant) and primary spike length (33.2 cm) compared to other dates of sowing. Castor intercropped with pigeonpea (1:1) with simultaneous sowing gave significantly higher seed yield than castor relay intercropped with pigeonpea staggered sowing at 15, 30, 45 and 60 DAS of pigeonpea. With delay in castor sowing at fortnightly intervals there was a drastic reduction in seed yield.

The data further revealed that maximum castor equivalent yield from both the years was recorded when castor was intercropped in pigeonpea (1:1) with simultaneous sowing followed by castor intercropped in pigeonpea (1:1) and sown after 15 DAS of pigeonpea. Economics of different treatments indicated that B:C ratio (3.21) from both the crops were higher when castor + pigeonpea were sown simultaneously. Similar results were reported by Patel *et al.* (2009) and Leela Rani (2008).

Thus, castor intercropped with pigeonpea (1:1) with simultaneous sowing was beneficial for maximizing the productivity of castor under rainfed conditions.

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Identification of crop production limiting factors in castor (*Ricinus communis* L.) in southern Telangana zone of Andhra Pradesh

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Abstract

Field experiments were conducted during rainy season of 2004, 2005 and 2008 at RARS, Palem, Andhra Pradesh to delineate crop production limiting factors in castor under resource constraint conditions. The studies suggested that non-adoption of weeding has been identified as the most critical factor as it reduced the seed yield of castor by 45 to 100%. It is followed by non-application of fertilizer and plant protection. Adoption of full package (weeding, fertilizer and plant protection) resulted in significantly higher seed yield of castor (1232 and 1064 kg/ha), net returns (₹ 11693 and 19390/ha) and B:C ratio (2.7 and 3.7). Next best treatment was full package-plant protection.

Keywords: Castor, production factors and resource constraints

Introduction

Castor (*Ricinus communis* L.) is an industrially important non-edible oil popular in semi-arid and arid regions. In Andhra Pradesh it is traditionally grown in southern Telangana Zone comprising of Mahaboobnagar, Nalgonda and Ranga Reddy districts. The crop is called as poor man's crop because it is mostly grown by resource poor farmers on less fertile red *chalka* soils purely under rainfed conditions often under-fertilized. Non-adoption of full package of agronomic practices is the reason why the productivity of castor is meager (400-500 kg/ha). Under the circumstances of limited resources, the castor growers can give maximum emphasis to those particular inputs which contributes maximum towards economic yield. Hence, delineation and prioritization of the components of whole package according to their contribution to seed yield is highly warranted. So, this research work on these aspects in castor was studied.

Materials and methods

The field studies were conducted at Regional Agricultural Research Station, Palem during rainy season of 2004, 2005 and 2008. The experimental soil was sandy loam having slightly acidity (pH: 6.7) and low in available N (238 kg/ha), high in available phosphorus (52.6 kg P_2O_5/ha) and potash (488 kg K_2O/ha). The experiment was laid in a randomized block design with eight treatment combinations (Table 1) and replicated thrice. The gross plot size was 5.4 m x 6.0 m and the net plot size was 4.8 m x 6.0 m. Crop was sown during first fortnight of July every season at 90 cm x 60 cm spacing. The weeding, fertilizer and plant protection measures were imposed as per the treatments. Total rainfall of 1078 mm (2004-05), 408 mm (2005) and 547.1 mm (2008) was received during the crop growth period. The crop was harvested in three pickings at monthly interval starting from 100 DAS. The data pertaining to the years 2004 and 2005 was presented based on pooled analysis while the data of 2008 was presented separately because no plant strand and yield could be recorded during the year.

Results and discussion

Adoption of full package (T_1) resulted in significantly higher seed yield of 1232 (2004 and 2005) and 1064 kg/ha (2008). The higher yield in this treatment was mainly because of higher plant stand (17000 and 15040/ha). Subba Reddy *et al.* (1999)

reported that adoption of full package i.e., use of improved seed, recommended dose of fertilizer and control of semilooper by the farmers increased the castor seed yield by 95% over normal practices adopted by the farmer. Among the individual production factors, non adoption of weeding (T_4) reduced seed yield by 45 to 100%. The yield reduction due to with drawl of fertilizer and plant protection was 44.5 and 26.0 %, respectively. Though reduction in the plant stand was less in T_4, T_6, T_7 and T_8 due to non adoption of weeding during 2004 and 2005 but no single plant could be found at first picking during 2008. This is mainly because of profuse growth of most dominant weed *Celsoia argentia* during the latter year which has shown complete smothering effect on the crop plants. The other weeds found are *Amaranthus* sp., *Cyperus rotundus, Cynodon dactylon, Commelina bengalensis* and *Digitaria sanguinalis*. At S.K. Nagar (Gujarat), nonadoption of weeding suppressed castor seed yield significantly by 2169 kg/ha followed closely by nonadoption of fertilizer inputs (1322 kg/ha) thus proving their importance in castor production (DOR, 2007).

The plant growth was stunted and did not grew taller in unfertilized treatment. Fertilizer is the next most important practice after weeding to enhance productivity of castor. The effect of production constraints on crop yield was found in the order of weeding > fertilizer > plant protection. Patel *et al.* (2008) reported that fertilizer > weeding > plant protection are important in S.K. Nagar, Gujarat. Samal (1990) explained the importance of fertilization to castor at recommended dose in increasing the castor yield as farmers are using only 25-50% of the recommended quantity in Mahboobnagar district.

Table 1 Effect of production factors on plant population, seed yield and economic returns of castor under rainfed conditions

Treatment	Final plant stand ('000/ha)		Seed yield (kg/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio	
	1	2	1	2	1	2	1	2	1	2
T_1 : Full package	17	15	1232	1064	18471	26600	11693	19390	2.7	3.7
T_2 : T_1 - F	16.5	17.2	684	681	10247	17025	4816	12025	2	3.4
T_3 : T_1 - PP	16.5	16.9	914	777	13713	19425	7722	13175	2.3	3.1
T_4 : T_1 - W	16.5	0	680	0	10203	0	4479	-5700	1.8	0
T_5 : T_1 - (F+PP)	16.5	18.7	507	572	7600	14300	3382	9500	1.8	3
T_6 : T_1 - (F+W)	15.9	0	319	0	4784	0	840	-4500	1.2	0
T_7 : T_1 - (PP+W)	15.9	0	409	0	6124	0	1196	-5350	1.2	0
T_8 : T_1 - (F+PP+W)	15.1	0	215	0	3217	0	61	-4000	1	0
SEm±	0.3	0.9	48	28						
CD (P=0.05)	0.9	2.8	146	84						

1 = Pooled data of the year 2004 and 2005; 2 = Data of the year 2008; Price of castor seed : ₹1500/q (2004 and 2005); ₹ 2500/q (2008); F = Fertilizer; PP = Plant protection; W = Weeding

The combinations of different resource constraints further reduced the yield of castor. Withdrawal of fertilizer and weeding from whole package (T_6: 319 kg/ha) reduced the seed yield by 26% in comparison with removal of fertilizer and plant protection measures from total package (T_5: 507 kg/ha) and T_7 (₹ 409 kg/ha), highlighting the importance of weeding and fertilizer management in castor than plant protection. Of all the treatments under test, withdrawal of fertilizer, plant protection and weeding from whole package (T_8: 215 kg/ha during 2004 and 2005 and no yield during 2008) reduced the seed yield by 83 to 100%. Similar results were also reported by Patel *et al.* (2008).

Economic analysis revealed that adoption of total package accrued greater monetary benefits (net return and B.C. ratio of ₹11693 to 19390/ha and 2.7 to 3.7, respectively). Subba Reddy *et al.* (1999) obtained additional cost:benefit ratio of 11.5 with weeding against non-adoption of weeding. Non adoption of weeding + fertilizer + plant protection measures in the whole package resulted in net return of ₹ 60/ha and ₹ 4000/ha. This indicates that non adoption of weeding and fertilizer either alone or in conjunction depressed the net returns to a greater extent.

Thus, weeding is the most critical component in increasing castor production, followed by application of fertilizer and plant protection. Adoption of full package of practices gave the highest seed yield and proved more remunerative in net return and benefit cost ratio.

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Response of castor to phosphorus fertilization

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Abstract

A field experient was conducted on medium black soil during rainy season of 2001 to 2004 to study the response of castor hybrid, GCH-6, to phosphorus (P) application. The pooled results of four years showed that yield attributing characters and seed yield of castor were significantly influenced by different P treatments. Application of 40 kg P_2O_5/ha recorded significantly higher yield attributing characters and seed yield of castor, but it remained statistically at par with 60 and 80 kg P_2O_5/ha. Maximum net returns was realised when castor crop was fertilized with 40 kg P_2O_5/ha which was closely followed by treatment 60 kg P_2O_5/ha. The application of 80 kg P_2O_5/ha recorded significantly high available soil P and remain at par with 60 kg P_2O_5/ha. Significantly low soil P was recorded in control i.e., no application of P.

Keywords: Castor, phosphorus, black soil

Introduction

Oilseed crops have a unique significance in recent era of energy crisis, as they play pivotal role in the agricultural industry and export trade of India. Castor (*Ricinus communis* L.) holds first position among the non-edible oilseeds and occupies 38 and 36% production and area, respectively in India. The major reason for increasing demand of castor has been attributed to the multiple use of castor oil such as making dyes, detergents, plaster of paris, soaps, oilments, cosmetics, rubber, lubricants, etc. The advent of improved varieties and also the release of hybrids necessitate the researchers to develop suitable agro technologies including nutrient requirements. the present study deals with the optimization of phosphorus (P) levels, in castor hybrid, GCH-6.

Materials and methods

A field experiment was conducted during rainy season of 2001 to 2004 at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat. The response of castor to P application was studied in castor hybrid, GCH-6 grown on medium black soil of south Saurastra agro-climatic zone of Gujarat. The experiment was laid out in a randomised block design with four replications and five levels of P *viz.*, 0, 20, 40, 60 and 80 kg P_2O_5/ha. The experimental soil was medium black and highly calcareous. Clay loam in texture. Slightly alkaline pH (7.9) in reaction and free from salinity. Medium in available N (223 kg/ha), P (27.5 kg/ha) and high in K (301 kg/ha). Phosphorus treatments were applied as basal, while a common dose of nitrogen @ 75 kg N/ha to each plot was applied in two equal splits, one at the time of sowing and second at one month after sowing. The plant height, number of branches/plant, number of spikes/plant, length of main spike, number of capsules/main spike were recorded on five randomly selected plants from each plot. The pick-wise seed yield was recorded. Soil samples were collected from each plot, and analysed for available P by standard procedures.

Results and discussion

Seed yield of castor and related attributes were significantly affected due to the different levels of P (Table 1). The pooled results over four years indicated that yield attributing characters and seed yield of castor were significnatly influenced by different P treatments.

***Table 1** Effect of phosphorus levels on castor (cv. GCH-6) yield attributes, seed yield, economics and soil available P_2O_5*

P level (kg/ha)	Plant popula-tion	Plant height (cm)	Inter nodes/ plant	Length of main spike (cm)	Branches/ plant	Spikes/ plant	Capsules/ main spike	100 seed weight (g)	Pooled seed yield (kg/ha)	Gross income (₹/ha)	Cost oc cultiva-tion (₹/ha)	Net income (₹/ha)	B:C ratio	Available P_2O_5 (kg/ha)
0	17967	119	16.6	47.9	3.7	4.6	51.5	31.7	2732	38248	10250	27998	2.7	72.5
20	17581	129	17.5	49.9	4.2	5.2	55.5	31.7	3122	43708	10648	33060	3.1	79
40	17912	137	17	59.2	5	6.3	68.5	32.4	3676	51464	11046	40418	3.7	84.5
60	17581	140	17.3	54.9	4.8	6.2	68.1	32	3493	48902	11444	37458	3.3	87
80	17581	137	17.2	52.8	4.3	5.7	68.5	31.7	3369	47166	11840	35326	3	92.2
SEm±	193	3.9	0.4	2.7	0.1	0.2	2.9	0.3	160					1.9
CD (P=0.05)	NS	12	NS	8.5	0.5	0.6	9.1	NS	494					5.9
CV (%)	4.3	6.5	4.8	9.3	17.4	15.9	10.8	3.7	9.7					4.6

Applicationof 40 kg P_2O_5/ha recorded significantly higher value of yield attributing characters and seed yield of castor (3676 kg/ha) over control and 80 kg P_2O_5/ha. However, it remained comparable with 60 kg P_2O_5/ha. Phosphorus is a plant nutrient involved in a wide range of plant processes from cell division to the development of a good root system and ensuring timely and uniform ripening. It also performs a number of functions related to growth, development, photosynthesis and utilization of carbohydrates (Tandon, 1991). In the present study, all the processes were supported to be favourably improved with 40 kg P_2O_5/ha along with 75 kg N and resulted into higher seed yield of castor. The present findings corroborates the results of Patel (1997), Sutaria *et al.* (1998) and Raghavaiah (1999). The application of 80 kg P_2O_5/ha recorded significantly high available soil P and remain at par with 60 kg P_2O_5/ha. Significantly low soil P was recorded in control i.e., no application of P.

Economics of different P treatments showed that the highest net return of ₹ 40418/ha was realised when castor crop was fertilized with 40 kg P_2O_5/ha. It was closely followed by 60 kg P_2O_5/ha (₹ 37458/ha). The lowest net return of ₹ 27998/ha was obtained under control. Similarly, highest C:B ratio was obtained with 40 kg P_2O_5/ha (3.66) followed by 60 kg P_2O_5/ha (3.27).

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Effect of sulphur nutrition on productivity of castor, *Ricinus communis* L.

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Abstract

A field experiment was conducted during rainy season of 2006-07 to 2008-09 to study the effect of different levels and sources of sulphur (S) on the productivity of castor in medium black soil under irrigated conditions. The pooled results of three years indicated that seed yield of castor responded significantly upto 20 kg S/ha. Among the S sources, gypsum was found superior to elemental S, but it remained at par with the single super phosphate. The applicationof 20 kg S/ha in the form of gypsum (154 kg/ha) along with recommended dose of nitrogen and phosphorus (75-40 kg/ha) as DAP and urea recorded signifcnatly higher seed yield (3078 kg/ha) than the rest of the treatments. However, it remained statistically at par with 20 kg S/ha applied as single super phosphate. The net return (₹ 45067/ha) and B:C ratio (3.3) also followed the similar trends.

Keywords: Castor, sulphur, gypsum, single super phosphate

Introduction

Castor is one of the most important commercial non-edible oilseed crops in Gujarat. The yield potentiality of castor can be exploited by adopting suitable recommended package of practices. Among the different factors responsible for augmenting the yield, balanced fertilisation play an important role. Generally the farmers use sulphur (S) free fertilizers like DAP, urea, etc. Hence, the soils generally suffer from S deficiency due to high yielding hybrids and depletion of S through leaching and soil erosion. Productivity of oilseed crops can be increased by application of S (Tandon, 1986; Gundalia and Golakiya, 1998). Sulphur is known to augment the oil content and seed yield of castor. The present investigation was undertaken to find out the optimum dose and suitable source of sulphur for increasing the castor productivity.

Materials and methods

The experiment was conducted during rainy season of 2006 to 2008 at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat under irrigated conditions. The experimental soil was medium black and highly calcareous. Clay loam in texture, slightly alkaline pH (7.8) in reaction and free from salinity. Available N, P_2O_5 and K_2O were 230, 27.5 and 320 kg/ha, respectively. The ten treatments comprised three levels (10, 20 and 30 kg S/ha) and three sources (gypsum, single super phosphate and elemental S) of S along with the control (without S). These treatments were examined in a randomised block design with three replications. The castor hybrid GCH-6 was sown at 90 cm x 60 cm spacing. A whole dose of the S containing fertilizers were applied to crop as per treatments. Full dose of phosphorus and half the dose of recommended fertilizers (75-40-00 kg NPK/ha) were applied commonly to all the plots. Remaining half dose of nitrogen was applied at 35 DAS of the crop. The pick-wise seed yield was recorded.

Results and discussion

The pooled results of three years (Table 1) indicated significant differences in yield attributes due to different levels and sources of sulphur. Application of 20 kg S/ha in the form of gypsum recorded significantly higher length of main spike and number of spikes/plant than the rest of the treatments. However, it remained at par with 30 kg S/ha in the form of gypsum. The application of 20 kg S/ha recorded significantly higher number of capsules/main spike and remained comparable with 20 kg S/ha int he form of single super phosphate and 30 kg S/ha in the form of gypsum or single super phosphate. Similarly, application of 20 kg S/ha in the form of gypsum recorded significantly higher castor seed yield (3079 kg/ha) than rest of the treatments. However, it remained statistically at par with 20 kg S/ha and 30 kg S/ha in the form of single super phosphate and 30 kg S/ha in the form of gypsum.

Increase in different yield attributing characters might be due to more availability of sulphur during the vegetative and reproductive stages of the crop. Sulphur is a part of amino acid (cystine), which helps in chlorophyll formation, photosynthetic process and activation of enzymes and seed formation. Increase in different yield attributing characters like spikes/plant, capsules/plant, length of main spike reflected an increase in total seed yield of castor. Similar, results were reported by Singh (1999).

Economics of different treatments indicated that the maximum net income of ₹ 45067/ha and a B:C ratio of 3.3 were obtained when castor crop was fertilized with 20 kg S/ha. It was closely followed by 20 kg S/ha as single super phosphate (₹ 38262/ha) and 30 kg S/ha as gypsum (₹ 41268/ha).

Thus, the application of 20 kg S/ha in the form of gypsum or single super phosphate along with recommended dose of nitrogen and phosphorus (75:40 kg/ha) was more remunerative and productive in cultivation of irrigated castor.

Table 1 Effect of sulphur levels and sources on yield attributes, seed yield and economics (cv. GCH-6)

Treatment	Plant height (cm)	Internodes/ plant	Branches/ plant	Length of main spike (cm)	Spikes/ plant	Capsules/ spike	100 seed weight (g)	Pooled seed yield (kg/ha)	Grass return (₹/ha)	Total cost (₹/ha)	Net returns (₹/ha)	B:C ratoo
Control	63.8	17.4	3.4	36.4	4.1	45.9	28.9	1625	34125	19490	14635	1.75
10 kg S/ha as SSP	68.3	17.5	4.4	39.1	4.6	51.4	30.1	2138	44898	19823	25075	2.26
10 kg S/ha as GP	68.8	18.3	4.7	41.7	5.4	56.6	30.2	2360	49560	20156	23404	2.46
10 kg S/ha as ELS	68.6	17.7	4.7	42	5.8	58.7	31.2	2175	45675	20489	25186	2.23
20 kg S/ha as SSP	72.7	17.5	5.5	44	6.1	65.3	31.9	2752	57792	19530	38262	2.96
20 kg S/ha as GP	80.5	17.6	6.3	50.8	7.7	71.4	30.2	3078	64638	19571	45067	3.3
20 kg S/ha as ELS	74.1	17.5	5	41.7	5.5	57.7	30.4	2509	52689	19611	33078	2.69
30 kg S/ha as SSP	80.2	17.7	5	44.8	6	65.5	30.4	2765	58065	19960	38105	2.91
30 kg S/ha as GP	77.1	18.1	6	47.4	7.7	70.7	29.8	2938	61698	20430	41268	3.02
30 kg S/ha as ELS	75	17.7	5.2	43.5	5.7	59.2	30	2589	54369	20900	33469	2.6
SEm±	4.5	0.3	0.2	1.6	0.3	2.8	0.4	155				
CD (P=0.05)	NS	NS	0.8	4.5	0.9	8.1	1.1	461				

SSP = Single super phosphate; GP = Gypsum; ELS = Elemental sulphur

Price of castor seed: ₹ 21/kg; Elemental sulphur ₹ 400/10kg bag; Single super phosphate ₹ 200/50 kg bag; Gypsum ₹ 605/tonne; Cost of cultivation (common) : ₹ 19490/ha

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Optimization of castor production under resource constraints

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Abstract

A field experiment was conducted on medium black soil during rainy season of 2004-05 to 2006-07 to assess the contribution of production factors on seed yield of castor. The pooled results of three years indicated that adoption of full package of prctices (fertilizer + weeding + plant protection) produced significantly higher yield (3518 kg/ha), net returns (₹ 36798/ha) and benefit cost ratio of 1.8. Among the various production constraints, fertilizer was found

to be crucial followed by weeding and plant protection. Fertilizer, weeding and plant protection are major important factors in Saurashtra region of Gujarat state in their contribution to yield of castor under irrigated conditions.

Keywords: *Castor, production factors, resource constraints*

Introduction

Castor (*Ricinus communis* L.) is one of the most important commercial non-edible oilseed crop in Saurashtra and north Gujarat. The yield potentiality of castor crop can be expoited by adopting suitable recommended package of practices. Among the different factors responsible for the augmenting the castor seed yield, fertilizer, plant protection and weeds are most important. However, the contribution of each factor for production of castor seed is limited and systematic research results are not available on these aspects and hence, the present study was initiated.

Materials and methods

A field experiment was conducted during rainy season of 2004 to 2006 at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat. The optimization of castor production under resource constraints was studied in castor hybrid GCH-6 grown on medium black soil of south Saurashtra agro-climatic zone of Gujarat.The experiment was laid out in a randomised block design with four replications and eight treatments (Table 1). The soil of expeimental field was medium black and highly calcareous clay loam in texture and slightly alkaline pH (7.8) in reaction. The treatments consisted of full package and deletion of one or more inputs like fertilizer, plant protection and weeding (Table 1). The plant height, number of branches/plant, number of spikes/plant, length of main spike, number of capsules/main spike were recorded on five randomly selected plants from each net plot and recorded for each treatment. The pickwise seed yield was recorded and pooled.

Table 1 Optimization of castor production under resource constraint (pooled data)

Treatments	Plant height (cm)	No. of nodes/plant	Branches/plant	Spikes/plant	Spike length (cm)	Capsules/spike	100 seed weight (g)
T_1 : Full package	137	18	4	7.5	60.3	76.4	36.3
T_2 : T_1 - F	120	18	4	4.5	44.4	68.3	35.9
T_3 : T_1 - PP	147	19	4.1	5.8	47.8	44.6	36.3
T_4 : T_1 - W	154	18	4.2	6	55.6	82.3	36.4
T_5 : T_1 - (F+PP)	125	18	3	4	46.6	49.6	35.7
T_6 : T_1 - (F+W)	116	19	3.1	3.8	40	59.8	34.7
T_7 : T_1 - (PP+W)	146	19	4.4	7.2	55.1	77.7	34.5
T_8 : T_1 - (F+PP+W)	113	18	3.7	4.3	42.7	43.1	34.6
SEm±	8.8	0.2	0.4	0.6	1.7	3.7	4.4
CD (P=0.05)	26.9	NS	NS	1.9	5	10.7	NS

F = Fertilizer; W = Weeding; PP = Plant protection

Results and discussion

The results (Table 1) indicated that adoption of full package has highest seed yield of castor than rest of the treatments. The pooled results of three years showed that adoption of full package recorded significant highest seed yield (3518 kg/ha) than rest of the treatments. Non-adoption of fertilizer alone (1924 kg/ha) and conjunction with weeding (1327 kg/ha) and plant protection (1861 kg/ha) had more deleterious effect on seed yield, there by indicating its critical nature as compared with non-adoption of weeding and plant protection. Studies conducted at various locations also indicated the need for adoption of full package of practices to obtain the highest castor yield (DOR, 2007; Vaghasiya and Kavani, 2009).

Table 2 Effect of different constraints on seed yield and economics of castor (pooled data)

Treatments	Seed yield (kg/ha)				Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
	2004	2005	2005	Pooled				
T_1 : Full package	3471	3495	3586	3518	19490	56288	36798	1.8
T_2 : T_1 - F	1675	1812	2285	1924	17485	30784	13299	0.8
T_3 : T_1 - PP	3016	2911	2189	2705	18530	43280	24750	1.3
T_4 : T_1 - W	2909	1742	2481	2377	16460	38032	21572	1.3
T_5 : T_1 - (F+PP)	1889	1604	2089	1861	16730	29776	13046	0.6
T_6 : T_1 - (F+W)	1663	988	1330	1327	14640	21232	6592	0.5
T_7 : T_1 - (PP+W)	2919	1856	2209	2328	15610	37248	21638	1.4
T_8 : T_1 - (F+PP+W)	1488	918	1130	1179	13740	18864	5124	0.4
SEm±	134	143	112	192				
CD (P=0.05)	408	435	341	583				
CV (%)	9.8	12.9	9	10.5				

F = Fertilizer; W = Weeding; PP = Plant protection

Economics of various treatments worked out based on pooled result (Table 2) revealed that adoption of full package had high gross income (₹ 56288/ha), net income (₹ 36798/ha) and B:C ratio (1.8) than the rest of the treatments. Among the production factors, non-adoption of fertilizer alone (₹ 13299/ha) or in injunction with weeding (₹ 6592/ha) or plant protection (₹ 21638/ha) accrued lowest net return and B:C ratio compared to full package.

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Evaluation of different vegetables as intercrops with castor, *Ricinus communis* L.

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Abstract

A field experiment was conducted at Hyderabad during 2001 and 2002 in Alfisols under rainfed conditions to identify suitable vegetable(s) as intercrop in castor to maximize productivity under rainfed conditions. Different vegetables either in 1 row or 2 rows were evaluated as intercrops between wide spaced castor rows. In a year of scanty rainfall (2001), the yield of intercropped castor was comparable with sole castor. The castor equivalent yield increased when castor was intercropped with clusterbean, cucumber and lablab. The net returns were increased when castor was intercropped with 2 rows of clusterbean, lablab and cucumber. In a drought year (2002), the seed yield of castor was adversely affected due to intercropping when compared with sole crop of castor. The castor-equivalent yield was greater when castor was intercropped with clusterbean and cucumber either in 1 or 2 rows. The net returns were more when castor was intercropped with clusterbean and cucumber either in 1 or 2 rows.

Keywords: Castor, intercropping, vegetables

Introduction

Castor (*Ricinus communis* L.) is one of the important non-edible oilseed crops that has great industrial and commercial value. A sizable area is under rainfed conditions where it is cultivated in marginal and sub marginal shallow soils with low inputs by the resource-poor farmers in Andhra Pradesh, Tamil Nadu, Karnataka and Orissa. Wide fluctuations in total amount of rainfall and its distribution received through South-West monsoon results in wide variation in productivity (Rao and Chakrabarthy 1997). Castor is grown both as a sole crop and often as a mixed or intercrops. It is ideally suited for intercropping systems owing to wider inter- and intra- row spacing. The risk during drought periods in rainfed areas can be minimized by adopting appropriate cropping systems which utilize the resources in an efficient way (Chetty 1983). The present study was undertaken with an objective to identify suitable intercrop(s) for maximum productivity.

Materials and methods

A field experiment was conducted during the rainy season of 2001 and 2002 on Alfisol at Directorate of Oilseeds Research, Hyderabad. The treatments consisting of 4 vegetables, *viz.*, clusterbean, frenchbean, lablab and cucumber sown either in 1 row or 2 rows between the castor rows spaced at 90 cm x 60 cm spacing. The trial was conducted in randomized block design with 9 treatments replicated thrice. The crops were sown with the onset of monsoon. Cucumber was sown 1 month after sowing of castor. The crops were grown with recommended cultivation practices under rainfed conditions. Sole and intercropping system of castor were received recommended dose of fertilizer (N, P_2O_5, K_2O) @ 60, 40, 30 kg/ha, respectively. No additional dose of fertilizer was applied to intercrops. Complete dose of P_2O_5 and K_2O and half N were applied at the time of sowing, while the remaining half was top-dressed 35 days after sowing. The yields of intercrops were converted into monetary terms and expressed as castor-equivalent yields for comparison. Castor-equivalent yields were analysed statistically for system productivity comparison. Pooled analysis was done for castor equivalent yield.

Results and discussion

As the years of experimentation were found to be significantly different, year-wise data were presented (Table 1). The amount of rainfall received during the crop season of 2001 and 2002 was 590 and 390 mm, respectively. Nearly one month dry spell occurred from the last week of June to July in 2001 (scanty rainfall year). During 2002 (drought year), two dry spells occurred during the second week of June-July and again in September. Castor yield was positively correlated with amount of rainfall received (r = 0.97).

Table 1 Productivity and economics of castor-based intercropping systems involving vegetables

Intercropping system	No. of intercrop rows	Castor seed yield (kg/ha)	Intercrop yield (kg/ha)	Castor equivalent yield (kg/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
2001							
Castor + clusterbean	1	1654	1483	1951	19506	10956	2.28
	2	1568	3096	2187	21872	11217	2.05
Castor + frenchbean	1	1405	361	1549	15494	6444	1.71
	2	1583	933	1956	19562	8907	1.83
Castor + lablab	1	1505	1568	1975	19754	11171	2.30
	2	1528	2423	2255	22549	12729	2.30
Castor + cucumber	1	1414	2792	2172	19724	11141	2.30
	2	1436	4602	2356	23564	13644	2.38
Sole castor		1821	-	1821	18210	10660	2.41
S Em±		85.2		113			
CD (P=0.05)		NS		325			
CV (%)		9.6		10.0			
2002							
Castor + clusterbean	1	393	4329	1259	12588	6548	2.08
	2	358	8338	2026	20256	12611	2.65
Castor + frenchbean	1	637	2421	1121	11210	5270	1.88
	2	577	3117	1185	11850	4405	1.59
Castor + lablab	1	314	1934	894	8942	3369	1.60
	2	328	2135	968	9685	2875	1.42
Castor + cucumber	1	694	4212	1536	15364	8791	2.34
	2	607	6513	2050	19096	11186	2.41
Sole castor		748	-	748	7480	5440	1.40
S Em±		53		101			
CD (P=0.05)		155		293			
CV (%)		19.0		15.4			

Scanty rainfall year (2001): The castor seed yield was not significantly differed under intercropping compared with its sole crop. Intercrops and castor used resources without competition, resulting in enhanced system productivity. The castor-equivalent yield was significantly greater in castor + cucumber, castor + clusterbean and castor + lablab intercropping systems either in 1 or 2 rows of intercrops than sole crop of castor. Similarly, higher gross returns were recorded in these systems than sole crop of castor. Intercropping of castor with clusterbean with 2 rows, lablab either in 1 or 2 rows and cucumber either in 1 or 2 rows are superior in terms of net returns. Castor intercropping with clusterbean was found productive and profitable in shallow soils. Therefore, clusterbean, cucumber and lablab were better compatible intercrops with castor. Sole crop of castor and other intercropping systems obtained greater benefit: cost ratio (> 2.00) except castor + frenchbean.

Drought year (2002): The castor seed yield was significantly decreased in intercropping systems compared to its sole crop. Jadhav *et al.* (1992) also reported reduction in seed yield of castor when intercropped with clusterbean. Double row of intercrops decreased the castor seed yield compared to 1 row of intercrops. Among the different intercropping systems, castor seed yield was least affected when intercropped with frenchbean and cucumber. Significantly lower castor seed yield was obtained when castor was intercropped with lablab and clusterbean perhaps these crops could have exhausted limited soil moisture. The castor-equivalent yield was significantly increased under intercropping with clusterbean and cucumber either in 1 or 2 rows. Intercropping of castor + clusterbean and castor + cucumber offered higher gross returns, net returns and benefit: cost ratio than sole castor. Intercropping of castor with clusterbean and cucumber systems exploited resources in a better way and increased the system productivity.

Thus, castor may be intercropped with 2 rows of clusterbean and cucumber between the wide-spaced castor rows for maximizing the productivity and profitability.

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Studies on recovery and regrowth of water stressed genotypes of castor, *Ricinus communis* L.

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Abstract

A field experiment was conducted to characterize the soil water stress, the effect of water stress on crop growth and the response of crop in terms of crop recovery and regrowth after stress relief. Low moisture status of 6.0 to 6.14% and its improvement in soil from 8.68 to 13.31% indicated onset of water stress and its subsequent relief. Six castor genotypes were screened in the study. Mean osmotic potential of the genotypes varied from -1.16 to -1.64 MPa. Genotypes Haritha, PCS 138 and Kranthi recorded high ?s indicating accumulation of solutes between -1.10 to -1.20 MPa under stress, whereas Haritha and Kiran recoded high ?s of -0.98 to -1.46 MPa upon relief from stress. SPAD chlorophyll meter readings (SCMR) decreased with the age of the crop from 36 to 28. Haritha, Kiran, PCS 137 showed high values indicating chlorophyll stability during water stress and after relief. Correlation matrix showed significant associations between traits like effective spike length with capsule number (r=0.906), 100 seed weight (0.932) and capsule number with 100 seed weight (r=0.991). Genotypes Haritha, Kiran, Kranthi which recorded drought tolerant traits have been recommended for cultivation in dry lands of Andhra Pradesh.

Keywords: Castor, recovery and regrowth, drought tolerant trait, osmotic potential, SCMR

Introduction

Drought, salinity and high temperature constitute the major constraints to realize the potential yields of crop plants. Crops grown on 90% of arable land, experience either singly or in combination different types of stress. Drought and heat tolerance are expected to become important as temperature rises and becomes more variable (Swapan Datta *et al.*, 2009). Water deficits continue to affect crops as a single major factor. The option to increase yield remains limited by way of extending irrigation and bring about improvement in productivity from dry land tracts. Genetic solutions offer promise to decrease the gap between actual and potential moisture limited yields by 30-40% (Udaya Kumar *et al.*, 2002).

Oilseed crops mainly grown in rainfed areas suffer from two types of stress *viz.*, intermittent drought and end of season drought. The response of the crops however, to various stresses has been quite complex and so far adequate information is lacking on various aspects of stress. In Andhra Pradesh, the productivity of castor has been 406 kg/ha as compared to India's average of 973 kg/ha (Damodaram and Hegde, 2007). Hence, it becomes imperative to understand and characterize the nature of stress, identify drought resistant traits and genotypes under water stressed situation and also quantify the effect of stress on crop upon relief through regrowth and recovery of genotypes. The present study aims at elucidating the response of castor genotypes and to suggest suitable genotypes with drought resistant traits for cultivation in dry lands.

Materials and methods

Six castor genotypes *viz.*, Haritha, VP1, Kranthi, Kiran, PCS 137 and PCS 138 were sown in Alfisols in randomized block design at the Agricultural College Farm, Rajendranagar during the rainy season of 2003. A spacing of 90 cm x 30 cm was adopted between rows and plants. The crop received 728.7 mm rainfall in 38 rainy days. The crop experienced two dry spells coinciding with initiation of primary spike (30-44 DAS) and maturity of secondary and initiation of tertiary spike orders (75-104 DAS). Castor genotypes were evaluated for their response to water stress and their capacity to recover and show regrowth upon relief of water stress. Soil water stress was quantified by gravimetric analysis. Crop water stress in terms of leaf osmotic potential was quantified by recovering the cell sap extracted from index leaf (2^{nd} or 3^{rd}) from top and estimated using Wescor vapour pressure osmometer. Chlorophyll content was estimated using SPAD meter (SPAD 502, Minolta Camera Corp, Ramsey, New Jersey). Five plants were selected randomly at 15 day interval for destructive analysis. The dry matter and leaf area produced by the genotypes was utilized to calculate crop growth rate (CGR), leaf area index (LAI) and specific leaf area (SLA) (Gardner *et al.*, 1988). Besides, seed yield and yield contributing characters were quantified. The results obtained were analyzed by two factorial randomized block design and the contribution of each character to yield was estimated by working out correlation matrix.

Results and discussion

Crop experienced water stress during the two dry spells. Soil during first and second dry spell recorded moisture content of 6.14 and 6.00% respectively. Plot with genotypes Kranthi, PCS 137 and PCS 138 during first dry spell and plots with VP-1, PCS 137 and PCS 138 during second dry spell recorded low levels of soil moisture (Table 1). Upon relief, mean soil moisture content increased to 13.31 and 8.68% respectively. Alfisols as such are repoted to have low water holding capacity (Prasad Rao and Bhupal Raj, 2001).

Cellular level responses which are essential to endure stress include maintenance of turgor, accumulation of potassium and soluble sugars (Babitha, 2003), build up of compatible solutes like proline, total soluble sugars, free amino acids and potassium (Levitt, 1980). Therefore, under such stressed situations genotypes that maintain high ψs need to be identified. In the present study, genotypes PCS 137, Kranthi and VP-1 recorded high ψs between -1.10 to -1.12 MPa. Quick recovery and regrowth was observed after relief from water stress in genotype Haritha followed by PCS 138 which recorded high ψs of -0.98 and -1.13 MPa (Table 1). During the second dry spell, Kranthi (-1.07) followed by Haritha (-1.20) and after relief Kiran (-1.35) followed by PCS 137 (-1.46) recorded high ψs.

Reliable and easily quantifiable plant parameters like chlorophyll content contribute to drought tolerance of genotypes. SPAD values in general decreased with the age of the crop (Table 1). The mean values during first dry spell and during recovery were 36 and 35, whereas the subsequent SCMR values at second dry spell and upon recovery were 30 and 28. Genotypes Haritha, PCS 137, PCS 138 during dry spell and PCS 137, Haritha after first dry spell, proved promising. In a similar trend PCS 137, Kiran during second dry spell and also after relief from stress, maintained stay green status. Interaction effect even reflected the superiority of PCS 137, Haritha and PCS 138 to maintain chlorophyll stability (table 1). Specific leaf nitrogen (SLN) with SLA and SLN with SCMR have been shown to have significant relationship. Hence, it has been reported that SCMR could be used as a reliable parameter to identify genotypes with low SLA or high SLN and in turn with high transpiration efficiency (Nageswar Rao *et al.*, 2001).

Correlation matrix for seven characters have been computed. Crop growth rate was observed to be sensitive to water stress. However, under stressed situations, production of high CGR i.e., drymatter and its accumulation leads to genotypes with low SLA (Gardner *et al.*, 1988) and consequently in identification of drought tolerant genotypes. Besides, a strong negative relationship between low SLA types and high WUE resulted in genotypes with thicker leaves and maintenance of high ψs. In the present study, low SLA was recorded in two genotypes VP-1 and PCS 138 (Jyothi *et al.*, 2006). Identification of such genotypes possessing high transpiration rates eventually resulted in high yields (Udaya Kumar *et al.*, 1998). In the present study, yield and yield contributing characters showed significant associations (Table 2). Effective spike length showed significant association with capsule number (r=0.906) and 100 seed weight (0.932). Capsule number in turn showed significant association with 100 seed weight (r=0.991). Two genotypes Haritha, Kranthi and Kiran possessing drought tolerant traits (Jyothi, 2004) and for their superior performance were released for cultivation in dry lands of Andhra Pradesh (Damodaram and Hegde, 2007).

Soil moisture status revealed that crop experienced water stress. Genotypes could be screened for their performance under water stress and for their recovery and regrowth under field conditions. Haritha, PCS 138 and Kranthi maintained high ψs. Haritha PCS 137, PCS 138 and Kiran showed high SCMR. ψs and SCMR can be considered as drought tolerant traits and incorporated in breeding programmes. Among the plant characters effective spike length correlated with capsule number, 100 seed weight and seed yield. Genotypes Haritha, Kiran and Kranthi can be recommended for cultivation in dry lands.

Table 1 Soil moisture, osmotic potential and SCMR during dry spell and after relief of water stress

Genotype	Soil moisture content (%)				Osmotic potential (Ψs) – MPa				SCMR			
	During 1st dry spell	After 1st dry spell	During 2nd dry spell	After 2nd dry spell	During 1st dry spell	After 1st dry spell	During 2nd dry spell	After 2nd dry spell	During 1st dry spell	After 1st dry spell	During 2nd dry spell	After 2nd dry spell
Haritha	6.65	13.75	6.75	8.38	-1.17	-0.98	-1.20	-1.76	37	37	31	27
VP – 1	6.25	13.25	5.25	9.25	-1.12	-1.17	-1.27	-1.87	36	35	28	27
Kranthi	5.75	13.25	6.75	8.25	-1.11	-1.17	-1.07	-1.77	35	31	25	25
Kiran	6.75	13.63	6.25	8.20	-1.25	-1.17	-1.52	-1.35	35	35	32	31
PCS137	5.75	12.75	5.13	8.82	-1.10	-1.30	-1.25	-1.46	37	38	34	31
PCS138	5.75	13.25	5.38	8.75	-1.23	-1.13	-1.35	-1.66	37	35	31	28
Mean	6.14	13.31	6.00	8.68	-1.16	-1.16	-1.27	-1.64	36	35	30	28
	SEm±	CD (P=0.05)			SEm±	CD (P=0.05)			SEm±	CD (P=0.05)		
G	0.08	0.13			0.02	0.02			0.29	0.58		
D	0.09	0.17			0.02	0.07			0.36	0.71		
G x D	0.22	0.42			0.06	0.11			0.49	0.75		

G = Genotype; D = Days after sowing

Table 2 Correlation matrix of growth, yield contributing characters and yield

Character	CGR	LAI	SLA	Spike length	Capsule number	100 seed weight	Yield
CGR	1.000	0.189	0.498	0.146	0.453	0.343	0.046
LAI	0.189	1.000	0.718	0.049	0.262	0.208	0.481
SLA	0.498	0.718	1.000	0.636	0.818	0.765	0.555
Spike length	0.146	0.049	0.636	1.000	0.906*	0.932*	0.596
Capsule number	0.453	0.262	0.818	0.906*	1.000	0.991*	0.671
100 seed weight	0.343	0.208	0.765	0.932*	0.991*	1.000	0.698
Yield	0.046	0.481	0.555	0.596	0.671	0.698	1.000

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Increasing castor productivity through soil texture improvement

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Abstract

Alfisols and related soils provide an opportunity of better drainage but suffer due to low water holding capacity. Low productivity of castor in Andhra Pradesh, Karnataka and Tamil Nadu is mainly due to its cultivation under rainfed conditions in Alfisols. The crop suffers due to droughts of different magnitudes resulting in low yield. For the same rainfall pattern, the length of growing period varies due to the variation in soil texture and depth. Applying excavated tank silt to course textured Alfisols (sandy loam) to 15cm depth has improved the water holding capacity and resulted in significant increase in seed yield of castor besides reducing the frequency of irrigation. The practice provides long term benefits and has many supplemental advantages for sustainable castor production.

Keywords: Textural modification, tank silt, irrigation frequency, seed yield and drought tolerance

Introduction

Overcoming the soil related limitations for increasing cropping intensity, crop productivity and better utilization of limited water resources is imminent for increasing agricultural production. Soil texture plays a very important role in influencing water holding capacity of soils. For a given climatic situation of rainfall, temperature and wind speed that determine the evaporative demand (potential evapo-transpiration), the length of growing period (LGP) varies due to the soil texture and depth, together determining the water holding capacity. The general soil textural components that make up the textural class of soil are sand, silt and clay. The proportion of these soil components in a soil determine the textural class as depicted in Fig.1.

Loam is the ideal soil texture for most crops with optimum water holding and release properties. Loams have ideal proportion of sand (35 to 50%), silt (75 to 90%) and clay (15 to 30%). Silt (< 0.05 mm to > 0.002 mm) forms the major component of a loamy soil. The poor water holding capacity of sandy soils or the poor infiltration capacity of clayey soils can be modified by addition of silt for better water relations and plant growth besides increasing organic matter content.

Silt is characterized by: particle size i.e., < 0.05 mm to > 0.002 mm (not visible to the naked eye); wet silt does not exhibit stickiness or plasticity or malleability, retains more water for plants and have slower drainage than sand, highly prone for water erosion and holds more plant nutrients than sand.

Soil texture is not subjected to change in the field. In nature, soil textural modification occurs over long periods (1000s of yrs) of pedologic processes and is prone for erosion. Soil texture can be modified in potting mixes or by physical transportation into agricultural land. Coarse textured soil (sandy) through external silt addition makes basic textural modification towards loam that usher multitude of benefits in terms of increased LGP, increased crop yields, increased nutrient use efficiency, environmental protection and conservation due to de-silting of tanks, natural soil fertility enhancement, support and distribute fauna and flora through transported soils, etc.

Owing to soil erosion by water, silt is transported into low lying areas and gets accumulated in rivers, ponds, tanks, lakes and dams. De-silting the tanks during summer when they are dry and applying the excavated silt to agricultural lands serves two purposes. One, increased water storage capacity of tanks with associated benefits of flood control, increased irrigated area or frequency of irrigation, etc. Second, the nutrient rich silt addition in agricultural land improves the soil fertility and water holding capacity. Besides the process provide rural employment during off-season. This has been the traditional practice in dry farming situations to supplement the soil fertility before the wide spread availability and use of fertilizers for crop nutrition.

Castor is an important industrial oilseed crop of the country leading the global production and productivity. The wide agro-ecological situations of castor cultivation in the country show wide productivity differences. The high productivity of castor in Gujarat and Rajasthan is due to its cultivation under irrigation with better soil fertility management under Aluvial soils. The low productivity in Andhra Pradesh and Karnataka is due to its cultivation under rainfed conditions with poor fertility management under shallow Alfisols. In Andhra Pradesh the crop is grown under rainfed conditions in large areas of Nalgonda, Mahabubnagar, Ranga Reddy and Medak districts. Drought is major factor for low crop yields. Castor crop faces many bouts of moisture stress from seedling, vegetative and filling stages. Depending on the severity of moisture stress, the seed yield from the respective spike order/s will be affected. The soil in the major castor growing districts is shallow Alfisols with sandy to sandy loam texture. Deep rooted castor can not penetrate deep because of hard pans and shallow profile, poor soil fertility and low water holding capacity. Increasing the carrying capacity of the available resources - land and moisture is critical for sustainable development of rainfed castor. The low productivity of castor is due to the drought situations the crop faces at more severity even for a moderate rainfall distribution mainly due to the poor water holding and release properties of sandy loams. While fertility can be managed with relative ease by fertilizer/manure application, water holding capacity can only be improved by modifying the soil texture towards silty loam.

The permanent way to improve water holding capacity of soil with marginal improvement in soil fertility is through soil texture improvement from sandy towards silt or clay. Varietal selection, suggested management practices and productivity depends on the available LGP, mostly decided by the soil conditions for the similar rainfall pattern in the region. The productivity and profitability can be surely improved by overcoming the moisture and nutrient limitations. This study attempts to find a solution to this inevitable natural situation occurring in the large areas in rainfed castor production zones of Andhra Pradesh, Karnataka and Tamil Nadu.

Materials and methods

Directorate of Oilseeds Research farm at Narkhoda village, Shamshabad mandal, Ranga Reddy district of Andhra Pradesh, India is situated in the Telangana region typically representing the region's agro-climatic situation. The soil is Alfisols (sandy loam with <15% clay, typical Chalkas) with a shallow depth ranging from 20 to 45cm. Climate (weather) based frequency of irrigation (5cm depth) required for meeting optimum crop water requirement during post rainy months (October to February) is 10 days and during summer months (February 2nd fort night to May) the frequency of irrigation increases to once in 5 to 7 days. The average seed yield of July planted castor extending up to April during 2001 to 2005 was about 1.0 to 1.2 t/ha when the annual rainfall varied between 660 to 850mm.

Excavated tank silt from the nearby large water body - Himayatsagar lake that dries out during the summer was applied in bunded rectangular K4, K5 and K6 plots of research farm each measuring 4000m^2, from April to June during the years 2005 and 2009 at the rate of 200 m^3 and 400 m^3, respectively, total amounting to the depth of 6 inches. The typical composition of tank silt applied was >90% silt and about 5% clay and rest as organic matter. After applying the silt in small heaps across the land area it was manually spread uniformly. Later, with tractor drawn disc plough and cultivator followed by disc harrow, it was incorporated. Castor crop for seed production (variety 48-1) was grown during the rainy season of 2005 and 2009.

Results and discussion

The physical properties of the soil after tank silt addition changed significantly. The soil colour has changed from red to grey with patchy red and gray soil peds initially and now the soil is more than 80% uniform.

The soil texture has changed from initial sandy loam to loam and silty loam. The possible textural modification to improve a course textured soil towards fine textured soil as depicted in Fig 2. The water holding capacity of the soil has increased significantly with field capacity increased by 25% and wilting point by 10%. Together, due to the increased water holding and retention capacity, the frequency of irrigation was reduced from 10-12 days to 18 days in post rainy season, while during summer it was reduced from 5-7 days to 12 to 15 days. The seed yield and test weight of tertiary and quaternary spike orders were significantly higher resulting in significant higher average seed yield ranging from 1.6 to 2.4t/ha. Owing to the positive textural modification the potential of castor crop to favorably utilize extended growing period due to indeterminate growth habit was optimally exploited resulting in higher yield from the later spike orders. Otherwise it would have resulted in lower test weight and yield due to insufficient soil moisture and hastened senescence. *Owing to the higher test weight, the oil content will also be higher resulting in higher oil yield. This improvement is especially significant for seed production plots that results in higher quality seeds with better vigour and germinability. Thus, the practice of soil textural modification has resulted in higher seed yield and quality with reduced irrigation frequency.*

Short term economics: (Additional costs and additional benefits)

- Cost of tank silt transportation and spreading: @ ₹ 175/m^3 for 15 cm depth = ₹ 2,62,500.00/ha (can be invested over two or five years).
- Additional gross returns from increased average seed yield = 800 kg/ha = @ ₹ 30/kg = ₹ 24,000.00/ha *(Seed production returns will be more than double)*
- Reduced irrigations: 40% = 5 irrigations (5 cm x 5 = 25 ha cm) = ₹ 7500.00/ha
- Total additional direct gain = ₹ 31,500/ha/crop

The benefits of textural modification will remain for many years and can continue for long period with very high returns on investment. Besides, the improved soil fertility and its direct benefits; higher nutrient use efficiency due to better moisture availability; crop survival during droughts; increased organic matter supporting more biota, etc, are the intangible benefits of great consequence. *The projected high cost varies widely and can be overlooked if the off-season employment and the free cost of the silt available in nearby tanks are made use of more gainfully.*

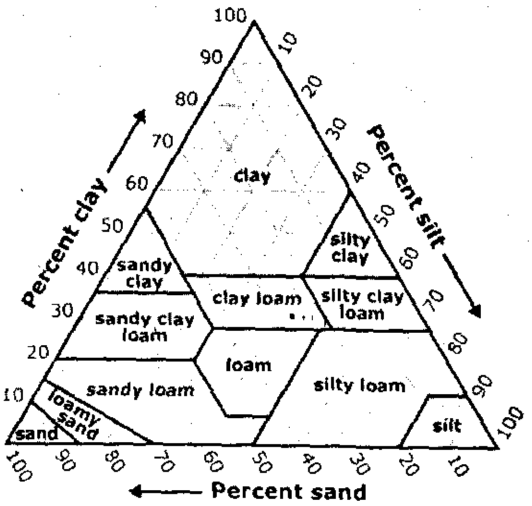
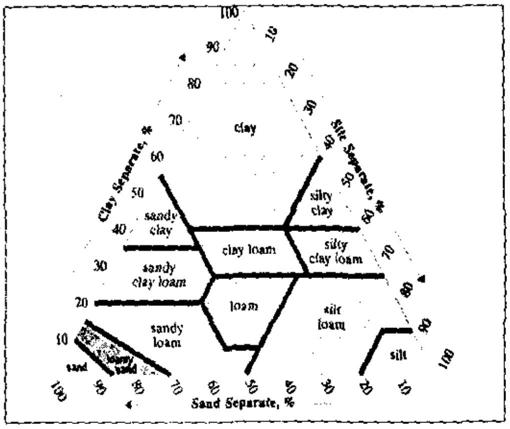
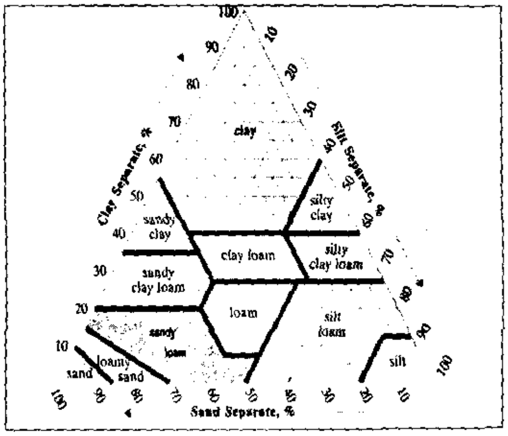


Fig. 1. Soil textural classification (USDA)

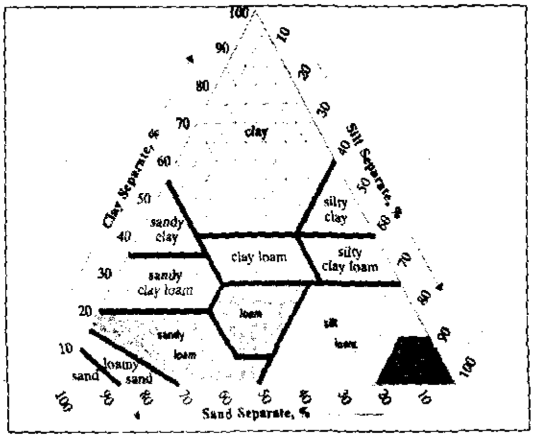
From | **To**



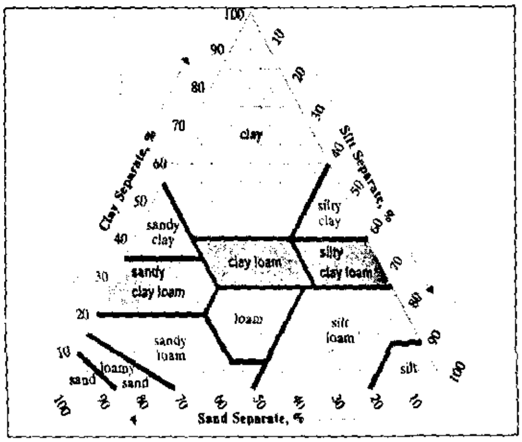
- **Coarse texture**
  - ☐ Sands
  - ☐ Loamy sands



- **Moderately coarse texture**
  - ☐ Sandy loam
  - ☐ Fine sandy loam



- **Medium texture**
  - ☐ Very fine sandy loam
  - ☐ Loam
  - ☐ Silt loam
  - ☐ Silt



- **Moderately fine texture**
  - ☐ Sandy clay loam
  - ☐ Clay loam
  - ☐ Silty clay loam

Fig. 2. Soil textural modification from course texture towards fine texture

Other aspects noticed due the practice of soil textural modification were: increased weed intensity and diversity, higher wilt incidence and increased stickiness of soil. As per the uniformity of mixing of soil, the individual plant growth and performance varied while the performance on area basis significantly improved.

Soil textural modification by addition of excavated tank silt to the shallow Alfisols (Chalkas) has improved the soil moisture relationships of the soil. With the total addition of 6" depth of tank silt in two spells have improved the water holding capacity resulting in increased seed yield of castor with reduced frequency of irrigation. The seed yield was increased by about 50% and the irrigation frequency reduced by 40% resulting in higher benefits. The high investment on silt transportation spread over few years can be reaped-over for many years with many supplemental advantages.

Evaluation of *Trichoderma* isolates against *Botrytis* grey rot of castor

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Abstract

Eighty-five isolates of *Trichoderma* were screened against *Botrytis ricini* by detached spike technique in initial screening. Out of 85 isolates, the reduction in disease incidence was highest in *T. harzianum* Th 4d (24%), followed by carbendazim 0.1% (22.5%).

Keywords: *Botrytis* grey rot, castor, *Trichoderma*

Introduction

Botrytis grey rot is a serious disease in Andhra Pradesh (Moses and Reddy, 1989) and Tamil Nadu (DOR, 1994). Epidemics of grey rot occurred in Andhra Pradesh in 1987 and in USA in 1958. The disease favoured by heavy rains during reproductive stage caused losses up to 100% (DOR, 1988). Use of fungicides to control grey rot diseases caused by *B. cinerea* in many crops has resulted in development of resistance in pathogen population. Efforts should be made to identify alternative control strategies. The present study was carried out to screen *Trichoderma* sp. strains for their biocontrol potential against *Botrytis ricini* that causes grey rot of spikes in castor.

Materials and methods

Trichoderma sp. strains were isolated from soil samples collected from different locations using *Trichoderma* specific medium (TSM) and cultures were maintained on potato dextrose agar (PDA). *Botrytis ricini,* which was maintained in DOR, Hyderabad was used to screen the strains of *Trichoderma* sp. *Trichoderma* strains were screened for their biocontrol potential against *Botrytis ricini* by detached spike technique in mist house. Spikes of castor (var.DCS 9) were kept in 150ml conical flask containing 2% sucrose solution. Spikes were sprayed with suspension of *Trichoderma* strains and inoculum of *botrytis* was sprayed after 24h. Treated spikes were transferred to glasshouse with fogging devices in which temperature maintains at 25 ± 2°C and relative humidity at 90%. The spikes were inspected daily for development of disease. Appropriate controls were included to confirm the antagonistic activity of the biocontrol agents. The per cent disease index and per cent reduction over control were calculated by taking the readings up to fifth day after the day of inoculation of pathogen.

Results and discussion

Eighty-five isolates of *Trichoderma* were screened against *Botrytis ricini* by detached spike technique in initial screening. Out of 85 isolates, 7 isolates were selected and screened again for their biocontrol potential against *Botrytis* gray rot. Incidence of disease was significantly reduced by *T. harzianum* Th 4d, *Trichoderma viride* Tv5 and fungicide carbendazim as compared to other strains. The *T. harzianum* Th 4d treatment resulted in a disease incidence of 62.3% and *T. viride* Tv5 treatment recorded a disease incidence of 66.3%, whereas the pathogen check recorded a disease incidence of 96.6%. Carbendazim 0.1% treatment recorded a disease incidence of 64.5% which was significantly less than pathogen check. The disease incidence recorded with other bioagent isolates *viz*., *T. harzianum* Th1, *T. viride* Tv 3, *T. viride* Tv7, *T. viride* Tv22 and *Trichoderma* sp.Tsp3 was not significantly different from pathogen check. The reduction in disease incidence was highest in *T. harzianum* Th 4d (24%) followed by carbendazim 0.1% (22.5%) and *T. viride* Tv 5 treatments (17.8%).

Table 1 Efficacy of *Trichoderma* strains against *Botrytis* grey rot in castor

Trichoderma isolates	Per cent disease index (PDI)	Reduction in disease (%)
T. harzianum Th1	85.5 (70.1)	5.1
T. viride Tv3	70.4 (60.4)	16.3
T. viride Tv7	79.2 (69.6)	12.1
T. harzianum Th 4d	62.3 (53.3)	24.0
T. viride Tv5	66.3 (58.7)	17.8
Trichoderma sp.Tsp3	81.2 (73.7)	10.1
T. viride Tv22	90.2 (81.2)	6.6
Carbendazim 0.1%	64.5 (56.2)	22.5
Pathogen check	96.6 (85.1)	-
C.D (P=0.05)	18.2	

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Integrated disease management of *Botrytis* grey rot of castor (*Ricinus communis* L.)

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Abstract

A field trial was conducted to assess the efficacy of different fungicides (Bavistin, and propiconazole), biocontrol agents (*Trichoderma viride* + *Pseudomonos fluorescens*), ethrel and salicylic acid. They were sprayed as prophylactic spray and after cyclonic rains, affected spikes were removed and application of nitrogen and potash was done in all treatments uniformly for management of *Botrytis* grey rot disease in castor. Lowest disease incidence (21.7%) was recorded in treatment T_2 (Prophylactic spray of bavistin 50 WP (1g/l) before cyclonic storm + removal of affected spikes + spray with bavistin (1g/1) + application of 20 kg N/ha + application of 20 kg K_2O/ha) followed by treatment T_5 and T_6 i.e., *Trichoderma viride* (0.3%) and Propiconazole (1ml/l) which recorded 23.3 and 26.7% disease incidence, respectively.

Keywords: *Botrytis ricini*, castor, integrated disease management

Introduction

Botrytis grey rot (BGR) caused by *Botrytis ricini* Godfrey is one of the major diseases of castor in Andhra Pradesh. The first epidemic of the disease appeared . during the rainy season of 1987 (Moses and Reddy, 1998) in Andhra Pradesh. BGR appears during cyclonic weather conditions causing severe yield losses. Under congenial conditions of high humidity and low temperatures the pathogen infects the flowers and capsules and converts them in to grey fungal mass of mycelium and spores. BGR is very serious in its infestation in the states of A.P. and Tamil Nadu, where it has virtually threatened castor cultivation. During the last 12 years, epidemic of BGR was reported in 4 years and in the remaining years the yield losses from 10 to 80% recorded. As cyclonic rain predispose the onset and spread of the disease, the disease incidence varies between the years (Janila *et al.*, 2006). IDM is most appropriate approach for disease management in the absence of source of resistance. No host resistance is reported so far against the disease in Andhra Pradesh and elsewhere. In the present investigation, studies were undertaken to identify effective control methods using cultural and chemical methods.

Materials and methods

Field trial was conducted at Regional Agricultural Research Station, Palem, Mahaboobnagar district in randomized block design with 3 replications and 8 treatments. All the chemical and bio-control treatments were imposed as prophylactic spray before the onset of cyclonic rains and the treatments were repeated 10 days after first spray. The removal of all affected spikes and a quantity of 20 kg N/ha and of 20 kg K_2O/ha was applied in all the treatments. The treatments included are: T_1 - Control; T_2 - Bavistin 50 WP (1 g/l); T_3 - Salicycilic acid(4µ/l); T_4 - Etherel 500ppm; T_5 - Propiconazole (1ml/l); T_6 - *Trichoderma viride* (0.3%); T_7 - *Pseudomonos fluorescens* (0.3%); T_8 - *Trichoderma viride* (0.3%) + *Pseudomonos fluorescens* (0.3%); T_9 - Removal of affected spikes + application of 20 kg N/ha + application of 20 kg K_2O/ha; T_{10} - Removal of affected spikes.

The experimental field was prepared well and the variety Haritha was sown with a spacing of 90 cm x 60 cm in the plots of 4.5 m x 6.0 m each. Two spraying of all treatments was done before onset of the disease and 10 days after first spray. Disease incidence in all the spike orders was recorded and per cent disease index was calculated.

Results and discussion

Botrytis grey rot incidence was recorded among all treatments and data presented in table 1. Lowest disease index (21.7%) was recorded in treatment T_2 (Prophylactic spray of bavistin 50 WP (1g/l) before cyclonic rains + removal of affected spikes + spray with bavistin (1g/1) + application of 20 kg N/ha + application of 20 kg K_2O/ha) followed by treatment T_5 and T_6 i.e., *Trichoderma viride* (0.3%) and propiconazole (1ml/l) which recorded 23.3 and 26.7% disease index respectively. Removal and burning of grey mold infected castor spikes/capsules has been recommended (Anonymous, 2002) for reducing the inoculum load of the pathogen. Removal and burial or burning of decaying infected plant tissues were proven as a practical measure to reduce *Botrytis* inoculum levels in field crops like tomatoes, lettuce, grapes and tulips (Maude, 1980). Madhu Meeta *et al.* (1996) and Rewal (1987) reported that spraying with carbendazim (0.1%) significantly reduced grey mold intensity in chickpea. Milkota *et al.*, (1996) tested different fungicides *viz.*, iprodione, vinclozolin, procymidone, dichlofluanid and folpet and reported that all of them were found to be effective in reducing grey mold incidence in grapes. Thus it can be concluded that, *Botrytis* grey rot in castor can be managed by application of prophylactic spray of bavistin 50 WP (1g/l) before onset of cyclonic weather followed by removal of affected spike and again spraying with bavistin (1g/l) on disease appearance.

Table 1 Integrated disease management for *Botrytis* grey rot of castor

Treatments	*Per cent disease index*
Control (No treatment)	55.0 (47.9)
Bavistin 50 WP (1 g/l)	21.7 (28.9)
Salicylic acid (4μ/l)	41.7(40.2)
Etherel 500ppm	50.1(45.0)
Propiconazole (1ml/l)	26.7(31.3)
Trichoderma viride (0.3%)	23.3(28.9)
Pseudomonos fluorescens (0.3%)	33.6(35.3)
Trichoderma viride (0.3%) + *Pseudomonos fluorescens* (0.3%)	29.8 (33.1)
Removal of affected spikes + application of 20 kg N/ha + application of 20 kg K_2O/ha	35.4(36.4)
Removal of affected spikes	38.3(38.2)
SEm±	1.1
CD (P=0.05)	4.1

Figures in parenthesis are angular transformed values; All values are mean of three replications

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Evaluation of consortia of *Trichoderma* spp. against *Botrytis* grey rot of castor

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Abstract

Out of 22 potential Trichoderma strains screened in vitro and in vivo against Botrytis grey rot of castor, nine isolates showed 70-79% disease reduction. The selected 9 Trichoderma isolates were found to be efficient in lytic enzyme production and phosphate solubilizion. Further, these nine efficient strains were screened in 36 combinations in vivo against grey rot. The consortia of Tv5 + T12, Tv33 + Tv3 and Th4d + Tv5 were found effective against the disease with 70-87% reduction over pathogen check. Trichoderma species applied as consortia were effective in control of Botrytis grey rot disease compared to individual isolates application.

Keywords: *Botrytis*, castor, consortium, *Trichoderma*

Introduction

Botrytis Grey Mold (BGM) caused by *Botrytis ricini* Godfrey is a serious disease of castor especially during continuous rains coupled with high humidity during capsule formation stage (AICRP, 1999). The epidemic of *Botrytis* grey rot occurred in Andhra Pradesh (Moses and Reddy, 1989) and Tamil Nadu that led to the decline in area under castor cultivation. As the pathogen is air borne, it is very difficult to control grey rot. Efforts to use of chemicals for control of the disease met with limited success and also *Botrytis* spp. have reported to develop resistance towards the regularly used fungicides (Haware and Mcdonald, 1992). The **present study shows the scope of biological agents as a possible alternative to fungicides for** managing the disease.

Materials and methods

Pathogens and bioagents: *B. ricini* culture was from culture collection of DOR, Hyderabad and it is maintained on castor leaf extract medium in the present study. *Trichoderma* spp. were isolated from different soil samples collected from all over India by using serial dilution technique (Johnson and Curl, 1972) on *Trichoderma* selective medium (TSM).

***In vivo* screening of individual as well as consortia of bioagents**: A greenhouse pot culture study was conducted to know the biocontrol potential of *Trichoderma* spp. and bacterial strains against *botrytis* grey rot of castor in greenhouse. Out of 22 *Trichoderma* isolates, nine *Trichoderma* strains have been short listed based on their *in vivo* biocontrol ability. Nine *Trichoderma* isolates were tried in 36 combinations against *Botrytis* grey rot of castor. The seeds of castor var. DCS 9 were sown in 30cm dia. pots and one plant was allowed to grow in each pot up to 60 days to obtain 1-2 spikes. The castor plants were shifted to mist house where a temperature of 28°C and humidity of above 85% was maintained. *Trichoderma* culture suspensions were prepared from 7-day old well-sporulated culture plates, spore concentration adjusted to 10^8 spores/ml and sprayed on castor spikes. *Botrytis* @10^6 spores /ml was sprayed 24h after bioagents spray. Grey mold incidence was recorded after 5 days and per cent disease index (PDI) calculated. Five replications were maintained for each treatment. The pot culture experiment was repeated twice.

Results and discussion

A total 22 *Trichoderma* strains were screened *in vivo* against grey rot in castor (Table 1). Nine *Trichoderma* isolates *viz.*, *Trichoderma* sp. TS4, *Trichoderma* sp. TS12, *T. viride* Tv3, *T. viride* Tv2, *T. viride* Tv5, *T. harzianum* Th4d, *Trichoderma* sp.T12, *T. viride* Tv33 and *T. viride* TvN13 that showed 65-79% disease reduction over pathogen check were selected.

Table 1 Efficacy of *Trichoderma* isolates against *botrytis* gray rot of castor under green house conditions

Name of bioagent	Per cent disease index (PDI)	Reduction in disease (%)
Trichoderma viride (Tv3)	22.4	65.0
Trichoderma viride (TvN13)	20.7	67.7
Trichoderma viride (Tv33)	21.2	66.9
Trichoderma sp. (T12)	18.8	70.6
Trichoderma sp. (TS4)	36.4	43.2
Trichoderma sp. (TS7)	50.5	21.3
Trichoderma sp. (TS9)	50.0	22.2
Trichoderma harzianum (TS10)	42.8	33.3
Trichoderma harzianum (TS12)	23.0	64.1
Trichoderma sp. (T8)	53.5	16.6
Trichoderma viride (Tv5)	19.2	70.6
Trichoderma harzianum (Th4d)	13.4	79.0
Trichoderma viride (Tv7)	20.5	68.0
Trichoderma sp. (TSP3)	39.1	39.0
Trichoderma sp. (TA5)	51.4	20.0
Trichoderma sp. (TS3)	46.4	27.8
Trichoderma viride (Tv22)	53.2	17.2
Trichoderma viride (Tv11)	36.6	43.0
Trichoderma viride (Tv2)	19.8	69.1
Trichoderma viride (Tv12)	33.5	47.8
Trichoderma viride (Tv8)	43.5	32.3
Trichoderma sp. (T4)	42.8	33.3
Carbendazim – 0.1%	22.2	65.3
Pathogen check	64.2	—
CD (P=0.05)	4.8	

Mean denotes mean value of 3 replications and arcsine transformed values have been presented.

Further, these nine *Trichoderma* isolates were tried as consortia in 36 combinations. Out of 36 combinations of *Trichoderma* strains, the consortia of *Trichoderma* sp.TS4+ *Trichoderma* sp.12, *T. viride* 33 + *T. viride* Tv3 and *T. harzianum* Th4d + *T. viride* Tv5 were found effective against *Botrytis* grey rot of castor with 70-87% reduction over pathogen check (Table 2). Raoof *et al.* (2003) also reported 45% disease reduction of *Botrytis* grey rot in castor with *Trichoderma viride*. *Trichoderma* *harzianum* was reported to suppress *Botrytis cinerea* in grapes (Dubos, 1984) and apple (Tronsmo, 1980) under field conditions. It may be concluded from the present study that consortia of *Trichoderma* are more effective than the individual isolates in controlling the grey mold disease in castor.

Table 2 *In vivo* evaluation of consortia of *Trichoderma* spp. against *Botrytis* grey rot of castor

Consortia	Per cent disease index	Reduction in disease over pathogen check (%)
Trichoderma sp. TS4 +*Trichoderma* sp 12	$27.0^{miknlhjo}$	70.0
Trichoderma sp. TS4 + *Trichoderma viride* Tv 2	37.2^{b}	38.2
Trichoderma sp. TS4 + *Trichoderma viride* Tv 33	27.4^{fcebdg}	54.5
Trichoderma sp. TS4 + *Trichoderma harzianum* S12	17.0^{hg}	71.8
Trichoderma sp. TS4 + *Trichoderma viride* Tv 13	12.1^{h}	79.9
Trichoderma sp. TS4 + *Trichoderma viride* Tv 3	25.9^{fcedg}	57.0
Trichoderma sp. TS4 + *Trichoderma harzianum* Th4d	22.3^{fehdg}	63.0
Trichoderma sp. TS4 + *Trichoderma viride* Tv 5	20.4^{fehdg}	66.1
Trichoderma sp. T12 +*Trichoderma viride* Tv 2	24.7^{fcedg}	59.0
Trichoderma sp. T12 + *Trichoderma viride* Tv 33	20.2^{fehdg}	66.4
Trichoderma sp. T12 + T. *harzianum* TS12	24.8^{fcedg}	58.8
Trichoderma sp. T12 + *Trichoderma viride* Tv N13	35.3^{cb}	41.4
Trichoderma sp. T12 + *Trichoderma viride* Tv 3	27.1^{fcebdg}	55.0
Trichoderma sp. T12 + *Trichoderma harzianum* Th4d	37.9^{b}	37.0
Trichoderma sp. T12 + *Trichoderma viride* Tv 5	34.0^{cb}	43.5
Trichoderma viride Tv33 + *Trichoderma harzianum* TS 12	25.4^{fcedg}	57.8
Trichoderma viride Tv33 + *Trichoderma viride* Tv N13	25.9^{fcedg}	57.0
Trichoderma viride Tv 33 + *Trichoderma* viride Tv 3	18.1^{mknljo}	79.9
Trichoderma viride Tv 33 + *Trichoderma harzianum* Th 4d	18.1^{fhg}	69.9
Trichoderma viride Tv 33 + *Trichoderma viride* Tv 5	52.3^{a}	13.1
Trichoderma harzianum TS12+*Trichoderma Viride* TvN13	26.9^{fcebdg}	55.3
Trichoderma harzianum TS 12 + *Trichoderma viride* Tv 3	27.7^{fcebdg}	54.0
Trichoderma harzianum TS12+*Trichoderma.harzianum* Th4d	25.6^{fcedg}	57.5
Trichoderma harzianum TS 12 + *Trichoderma viride* Tv 5	29.7^{cebd}	50.7
Trichoderma viride Tv N13 + *Trichoderma viride* Tv 3	27.1^{fcebdg}	55.0
Trichoderma viride Tv N13 + *Trichodermaharzianum* Th4d	28.0^{fcebdg}	53.5
Trichoderma viride Tv N13 + *Trichoderma viride* Tv 5	31.2^{cbd}	48.2
Trichoderma viride Tv 3+ *Trichoderma harzianum* Th4d	18.0^{fhg}	70.1
Trichoderma viride Tv 3+ Trichoderma viride Tv 5	19.1^{fehg}	68.3
Trichoderma harzianum Th4d + *Trichoderma viride* Tv 5	11.1^{mnlo}	87.7
Trichoderma viride Tv 2 + *Trichoderma viride* Tv 33	25.0^{fcedg}	58.5
Trichoderma viride Tv 2 + *Trichoderma harzianum* TS12	27.0^{fcebdg}	55.1
Trichoderma viride Tv 2 + *Trichoderma viride* Tv N13	28.6^{fcebd}	52.5
Trichoderma viride Tv 2 + *Trichoderma viride* Tv 3	27.0^{fcebdg}	55.1
Trichoderma viride Tv 2 + *Trichoderma harzianum* Th4d	29.7^{cebd}	50.7
Trichoderma viride Tv 2 + *Trichoderma viride* Tv 5	28.8^{fcbed}	52.2
Carbendazim – 0.1 %	5.5^{i}	94.7
Pathogen check	60.2^{a}	-

Mean values (arcsine transformed) in the same column followed by same letters are not significantly different according to Duncan Multiple Range Test at P = 0.05

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Efficacy of biocontrol agents against *Botrytis* grey rot of castor under field conditions

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Abstract

Botrytis grey mold disease caused by _Botrytis ricini_ in castor (_Ricinus communis_ L.) is one of the major diseases of economic importance in India. The present study show biological control efficacy of _Trichoderma_ sp. and bacterial strains against _Botrytis_. Efficient _Trichoderma_ (_T. viride_, Tv5, _T. harzianum_, Th4d, _Trichoderma_ sp. T12) and Bacteria (_Bacillus subtilis, Bacillus megaterium_ and _Pseudomonas fluorescens_ Pf 2) isolates were evaluated under field conditions. The isolates _Trichoderma_ Th4d and _Pseudomonas flourescens_ Pf 2 showed highest reduction of disease (>50%) under field evaluation. Persistence level of _Trichoderma_ spp. and bacterial strains (powder formulations) on the capsules of castor were examined at weekly intervals and found that _T. harzianum_ Th4d and _Pseudomonas fluorescens_ Pf2 sustained good number of viable propagules up to two weeks. All these biocontrol agents showed good shelf life both under room temperature and at 4°C upto 420 days.

Keywords: *Botrytis*, biocontrol, castor

Introduction

Castor, *Ricinus communis* L., is grown in many countries including India for its prized lubricant oil. The Indian productivity of castor (1094kg/ha) is more than that of world (984 kg/ha). The productivity of castor in Andhra Pradesh is much lower (454 kg/ha) due to biotic and abiotic stresses (Damodaram and Hegde, 2005).Among the biotic stresses, grey rot caused by *Botrytis ricini* Godrey is one of the major foliar disease occurring upto 100 % under congenial weather conditions (AICRP, 1988). In India the disease attained epidemic proportion in 1987 (Moses and Reddy, 1989). Recommended chemical management involves spraying 0.1% carbendazim before the onset of the rains based on the weather forecast and repeating the sprays after cessation of rains (AICRP, 2006). Although chemical control gives immediate control of the disease, their constant use may lead to environmental pollution, thus destroying the natural flora and fauna, creating instability in the ecological balance. *Botrytis* spp. have been reported to develop resistance towards the regularly used fungicides (Haware and Mcdonald, 1992). Biocontrol agents are a possible alternative to fungicides. *Trichoderma harzianum* was reported to suppress *Botrytis cinerea* in grapes (Dubos, 1984) and apple (Tronsmo, 1980) under field conditions. The use of *Trichoderma* and *Pseudomonas fluorescens* on different crops (Beastly *et al.*, 2000, Boer *et al.*, 1998, Xu *et al.*, 1993) in plant disease management has been well documented. Therefore an attempt was made to study the effect of *Trichoderma* and bacteria effect on the incidence of grey mold under field conditions.

Materials and methods

A field experiment was taken up in randomized block design with three replications to evaluate efficient bioagents against *Botrytis* grey rot of castor during the rainy season of 2008 in Directorate of Oilseeds Research farm, Rajendranagar, Hyderabad. The bioagent treatments were *T. viride*, Tv5, *T. harzianum*, Th4d, *Trichoderma* sp. T12, *Bacillus subtilis*, *Bacillus megaterium* and *Pseudomonas fluorescens* Pf 2. Fungicide treatment (Carbendazim 0.1%) and a pathogen check were also maintained. Bioagents and chemical spray were given on maturing spikes. *Trichoderma* powder formulations are being prepared with spore concentration of 10^7spores cfu/g and bacteria @ 10^9cfu/g sprayed on castor spikes. After 2 days of bioagents treatment, the spikes were challenge inoculated with spore suspension of the pathogen. The second bioagents and fungicide spray was given after 7 days. A field fogging technique has been developed and fogging was done 4 times a day with a duration of 15 min. to create conductive environment for the pathogen and bioagents development. The percent disease index in each treatment was recorded and data has been analyzed statistically. Persistence of bioagents on the castor spikes has been determined at 1st and 2nd week after spray by using serial dilution technique (Johnson and Curl, 1972) and density of bioagents was recorded accordingly. Shelf-life analysis of powder formulations potential bioagents *viz.*, *Trichoderma harzianum*, Th4d, *Trichoderma viride* Tv5, *Trichoderma harzianum*, TS12 and *Pseudomonas fluorescens*, Pf2 stored in white polythene bags for 14-month period was done at two different storage temperatures *viz.*, 4°C and 30°C. Colony forming units (CFU) of *Trichoderma* sp. with initial concentration of 10^8 cfu/g and *Pseudomonas fluorescens* Pf2 with initial conc. of 10^{10}cfu/g were enumerated at every 2 months intervals.

Results and discussion

Three *Trichoderma* spp. and three bacterial isolates were evaluated under field conditions against *Botrytis* grey rot of castor (Table 1). Among 3 strains of *Trichoderma* spp., *Trichoderma harzianum* Th4d was found to be very effective by showing 46.7% reduction in disease incidence followed by *T. viride* Tv 5 with a disease reduction of 42.6%. Biocontrol of *Botrytis* spp. through the mode of substrate competition by *Trichoderma* spp., *Gliocladium roseum* and other antagonists on leaves of different hosts was also reported by many workers (Elad, 1996; Prasad *et al.*, 1998; Sutton and Peng, 1993). Among bacteria, *Pseudomonas fluorescens* 2 showed highest reduction (56.1%) in disease incidence. Earlier studies show that *Pseudomonas fluorescens* could suppress *Botrytis* blight up to 87% in petunia flowers (Gould *et al.*, 1996).

Table 1 Efficacy of biocontrol agents against *Botrytis* grey rot of castor in field conditions

Treatments	Per cent disease index (PDI)*	Reduction over check (%)
Trichoderma viride Tv5 @ 10g / L	26.4 ^{bc}	42.6
Trichoderma harzianum Th4d @ 10g / L	24.5b^{cd}	46.7
Trichoderma sp. T12 @ 10g / L	25.8 ^{bc}	43.9
Bacillus subtilis 1 @ 10g / L	31.7 ^{b}	31.1
Bacillus megaterium 1 @ 10g/ L	21.2 ^{bdc}	53.9
Pseudomonas fluorescens Pf 2 @ 10g/ L	20.2 ^{bcde}	56.1
Carbendazim – 0.1 %	25.1^{bcd}	82.4
Pathogen check	46.0^{a}	0.0

Values in the parentheses are arcsine transformed. Values in the column followed by same letters are not significantly different according to Duncan Multiple Range Test at P=0.05

Table 2 Persistence of biocontrol agents (powder formulation) on the capsules of castor

Isolates	Viable propagules (log cfu/gm) on capsules of castor.	
	At 7 days of spray	At 14 days after spray
Trichoderma viride Tv5	3.78	3.61
Trichoderma sp.T12	3.95	3.86
Trichoderma harzianum Th4d	4.11	4.00
Bacillus subtilis	6.61	6.52
Bacillus megaterium	7.89	7.81
Pseudomonas fluorescens Pf2	7.97	7.83
CD (P=0.05)	2.24	2.1

Table 3 Shelf life of powder formulations *Trichoderma* spp. and *Pseudomonas fluorescens* Pf2

Storage Period (Days)	Viable propagules (log cfu/g)							
	Trichoderma harzianum Th4d		*Trichoderma viride* Tv5		*Trichoderma* sp .T12		*Pseudomonas fluorescens* Pf2	
	4°C	30±2°C	4°C	30±2°C	4°C	30±2°C	4°C	30±2°C
Initial	8.47	8.47	8.90	8.90	8.60	8.60	10.08	10.08
60	8.12	7.73	8.28	8.11	8.30	7.78	9.60	8.74
120	7.88	7.30	8.00	7.65	7.98	7.85	8.74	7.84
180	7.67	7.15	7.33	7.05	7.79	7.63	8.0	7.88
240	7.38	6.95	7.10	6.90	7.59	7.43	7.85	7.00
300	7.12	6.69	6.87	6.58	7.38	7.18	7.52	6.83
360	6.93	6.48	6.69	6.37	7.13	6.96	7.34	6.65
420	6.78	6.32	6.46	6.25	6.94	6.68	7.12	6.36
CD (P=0.05)	2.0	2.4	1.5	2.1	2.3	2.4	2.0	2.0

Persistence level of biocontrol agents (powder formulations) on the capsules of castor (Table 2) was examined at weekly intervals and found that *T. harzianum* TS12, *T. harzianum* Th4d and *P. fluorescens* 2 sustained with high density upto two weeks and that could have resulted less disease incidence due to bioagents competition for space and nutrition and also due mycoparasitic activity . Application of antagonists to foliar parts would avoid prior colonization of the tissues by the pathogen and by indigenous saprotrophs, and improve prospects for effective biocontrol (Sutton and Peng, 1993).

Shelf life study of *Trichoderma* spp. and *Pseudomonas fluorescens* Pf2 in talc based powder formulations stored at room temperature (30 ±2°C) and at 4°C showed that the *Trichoderma* spp. and *P. fluorescens* Pf 2 retained more than 6.0 log cfu/g even after 420 days of storage. Thus, it may be concluded from the present studies that foliar spray of bioagents are effective in reducing grey mold disease incidence in castor with better persistence apart from that these bioagents retained good shelf life for more than 420 days indicating scope for commercial exploitation.

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Standardization of inoculation technique for the evaluation of castor genotypes against root rot, *Macrophomina phaseolina* (Tassi) Goid

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Abstract

Root rot caused by *Macrophomina phaseolina* (Tassi) Goid is an important destructive disease of castor in the Saurashtra region of Gujarat. To standardize an efficient, reliable and quicker inoculation technique for screening castor genotypes against root rot, five inoculation methods i.e., stem-tape, root dip, blotting paper, toothpick and infested soil were studied on susceptible castor hybrid, GCH-4 sown in pots in a completely randomized block design with four replications having five plants each. The appearance and the development of various types of symptoms recorded at intervals indicated that there was significant difference in disease severity and symptom development under different inoculation techniques. The maximum disease incidence (100%) was observed at 15 days after inoculation (DAI) in the stem-tape inoculation method followed by root dip (95%), blotting paper (85%) and infected soil (78.7%). Disease incidence was significantly higher that caused drooping of the plant within 3-4 days in stem tape inoculation method. Abundant pycnidia and sclerotia were also formed on the area of the stem lesion. Therefore, stem tape inoculation method is identified as the most reliable, effective and quicker method for rapid screening for identifying resistant sources to root rot of castor.

Keywords: Castor, *Macrophomina phaseolina*, root rot, stem tape inoculation technique

Introduction

Among the non-edible oilseed crops, castor (*Ricinus communis* L.) occupies an important position in the economy of oilseeds throughout the world. The widely distributed diseases of castor are root rot *Macrophomina phaseolina* (Tassi) Goid and wilt caused by *Fusarium oxysporum* f. sp. *ricini*. Root rot is one of the major diseases that occur in a very severe form causing very high mortality in many farmers' fields. *M. phaseolina* is a soil borne pathogen that attacks the root and collar regions of the plant. Soil inoculation has been the usual method adopted for determining the pathogenic behaviour of the organism on host plants. To screen large number of castor germplasm and breeding materials against root rot disease for the detection of resistant sources, an efficient, reliable and quicker method is a prerequisite. Grezes-Besset *et al.* (1996) has described different inoculation techniques *viz.*, blotting-paper inoculation method, stem tape inoculation method, toothpick inoculation method for the evaluation of castor bean resistant to sclerotial wilt disease caused by *M. phaseolina*. Root dip inoculation technique has been carried out for identifying resistant materials to *Fusarium* wilt disease in castor (Raoof and Rao, 1996). The screening under sick plot conditions is time consuming and laborious. Moreover, the progress of disease development by soil inoculation method or in sick plot mainly depends on the prevailing environmental condition that can not be manipulated. So far, there has been no rapid inoculation method standardized for screening resistant sources against root rot of castor. Therefore, to standardize an efficient, reliable and quicker inoculation technique for screening castor genotypes to root rot, five inoculation techniques were studied on a susceptible castor hybrid GCH-4.

Materials and methods

Five inoculation methods were studied on a susceptible castor hybrid, GCH-4 in this investigation. In stem tape inoculation method, plants were maintained in pots containing sterilized soil under greenhouse conditions at an average temperature of 30°C for one month. The hypocotyl region of the plants was superficially wounded by peeling the epidermis at 2 cm above the soil surface. A mycelial disc of 4 mm in diameter was placed on the wound and covered it with cellophane tape. Control plants were wounded and were inoculated with a sterile PDA disc. Disease incidence was recorded on seven and 15 days after the inoculation by assessing the percentage of dead plants and the length of lesion on the stems. In root-dip inoculation method, the roots of the uprooted young seedlings (15 days old) were washed and immersed in a conical flask containing fresh culture suspension. Control plants were immersed in sterilized distill water. The level of disease was recorded at seven and fifteen days after the inoculation by counting the dead plants and measuring the discoloured area on the infected root. In blotting paper inoculation method, seven days old seedlings grown in pots containing sterilized soil were uprooted and washed. A mycelial disc of 4 mm size was kept on the middle of the taproot of each seedling. The seedling was then placed between two sheets of blotting papers. The upper part of the blotting paper was rolled around a small glass rod and the two blotting paper sheets were stapled. The seedling was suspended with the glass rod in a flask containing water and was kept under laboratory conditions. In control, non inoculated PDA disc of 4 mm size was kept in the middle of the taproot of each seedling. Individual seedlings were scored on seven and fifteen days after the inoculation for the extent infection in their roots (length of root lesion). In the toothpick inoculation method, inoculum of *M. phaseolina* was produced on sterile toothpicks. Toothpicks were loosely packed in glass jars containing potato dextrose broth covering the lower one third of the toothpicks. These jars were autoclaved twice for 20 min. at 120°C. The toothpicks were plated after cooling on PDA containing 4-day old *M. phaseolina* culture and incubated in darkness at 28°C. Ten days after incubation, one month old plants maintained in pots containing sterilized soil were inoculated by inserting these toothpicks in the middle of the first internodes. Control plants were inoculated with non-infested toothpicks. Disease level was calculated by measuring lesion on the stem and also by counting the dead plants after 15 and 30 days after inoculation. In soil inoculation method, the fungus was multiplied in SSM and was mixed (approx. 4000 sclerotia in 15 cm diameter pot) with the sterilized soil in pots. Surface sterilized seeds were then sown after about a week of establishment of the inoculum in the soil. Control plants were kept without inoculum. Observations were recorded at 15 and 30 days after the inoculation by counting the dead plants and measuring the discoloured area on the stem. All the above inoculation techniques were conducted in a completely randomized block design with four replications having five plants each. Separate controls were kept for each method. The inoculated plants were observed regularly for the appearance and development of the various types of symptoms *viz.*, seedling blight, fleshy rot, collar rot, twig blight and root rot.

Results and discussion

The data obtained from the five inoculation methods (stem-tape, root dip, blotting paper, toothpick and infested soil) revealed that there was significant difference in the disease severity and symptom development under different inoculation techniques (Table 1). The maximum disease incidence (100%) was observed at 15 days after inoculation (DAI) in the stem-tape inoculation method (Fig.1) followed by root dip (95%), blotting paper (85%) and soil (78.7%) inoculation methods. Toothpick inoculation method was the least effective exhibiting the minimum disease incidence (60%) as compared to the other methods. Root lesion (100%) was observed in the root dip and blotting paper inoculation methods after 15 days of inoculation whereas stem lesion was observed in stem-tape inoculation method (2-10 cm) after 15 days of inoculation. However, in toothpick (3-5 cm) and soil (1-4 cm) inoculation methods stem lesion appeared after 30 days of inoculation (Table 1).

The time of appearance of symptoms in different inoculation methods *viz.*, stem-tape (3-4 DAI), root dip (3-5 DAI), blotting paper (5-6 DAI), toothpick (20-22 DAI) and soil (23 DAI) were different. In stem-tape inoculation method, brownish discolouration developed around the inoculated region, and later the lesion progressed upward and downward (Fig. 2) with subsequent invasion of death of cortical tissues causing drooping of the plant within 3-4 days. Under high humidity conditions, abundant pycnidia were formed on the area of the stem lesion i.e., above and below the portion of the inoculated area (Fig. 3). Abundant sclerotia were also produced on the inner and outer surfaces of loosened sheath of roots and collar region. The plants infected with the root dip inoculation method exhibited drooping of plants within 3-5 DAI. The uprooted seedlings showed browning at the collar region loosening of root sheath and rotting of the root. In blotting paper inoculation method, drooping of plants started at 5-6 DAI. Symptoms such as blackish discolouration at the collar region and rotting of tap root and secondary roots of the infected plants were observed. Initially, the plants infected with the toothpick inoculation method showed blackish discolouration at the nodal region and drooping of terminal leaves at a later stage. While in the case of soil inoculation method, yellowing and drooping of the terminal leaves, withering of the entire branch or the entire plant, blackening at the collar region and rotting of the roots were observed.

As compared to the other methods assessed, in stem tape inoculation method, incubation period was minimum and the disease incidence was significantly higher that caused drooping of the plant within 3-4 days. Moreover, abundant pycnidia and sclerotia were also formed on the area of the stem lesion and on loosened sheaths of the roots respectively. According to Pan *et al.* (1981) the varieties of jute which showed no infection of *M. phaseolina* under soil inoculation, recorded 100% mortality with stem inoculation. Moreover, the superiority of stem inoculation has further established the fact that unknown pathogen-soil-microbe interaction can be eliminated. The root dip inoculation technique has been carried out as a standard technique for identifying resistant materials to *Fusarium* wilt disease in castor (Raoof and Rao, 1996). In both stem tape inoculation and root dip inoculation methods, injury made by vertical incision on collar region or trimming of the roots helped the mycelium to enter into the host. It is confirmed by the present investigation that the stem tape inoculation method is the most reliable, effective and quicker method for rapid screening for identifying resistant sources to root rot of castor. A large number of breeding materials can be screened within a short period by stem tape inoculation method which can save the time, area and manpower.

Table 1 Disease incidence and symptoms developed at various inoculation methods

Method of inoculation	Time of inocul-ation	No. of plants	Time of observation (days after inoculation)	No. of infected plants	Disease incidence (%)*	Length of stem/root lesion	Major symptoms
Stem-tape inoculation	30 DAS	20	7	12	60.0	1-3 cm	Brownish discolouration above and below the inoculated area of the stem followed by drooping of top of the plant and formation of pycnidia on the stem lesion.
			15	20	100.0	2-10 cm	
Root dip inoculation	15 DAS	20	7	12	60.0	--	Browning at collar region, drooping of plants, loosening of root sheath and rotting of the root in infected plant.
			15	19	95.0	100%	
Blotting paper inoculation	7DAS	20	7	8	40.0		Blackish discolouration at collar region and soft rotting and drooping of plant.
			15	17	85.0	100%	
Toothpick inoculation	30 DAS	20	15	0	0.0	--	Blackish discolouration at nodal region and drooping of terminal leaves.
			30	14	60.0	3-5 cm	
Soil inoculation	One week before sowing	19	15	0	0.0	--	Pale yellowish discolouration and drooping of terminal leaves followed by wilting of entire plant.
			30	15	78.6	1-4 cm	
SEm. ±					4.8		
CD (P=0.05)					14.4		
CV (%)					13.3		


Fig. 1. Inoculated (L) and control (R)

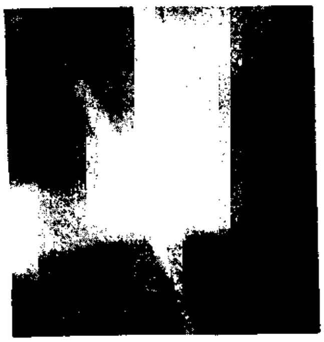
Fig. 2. Stem lesion

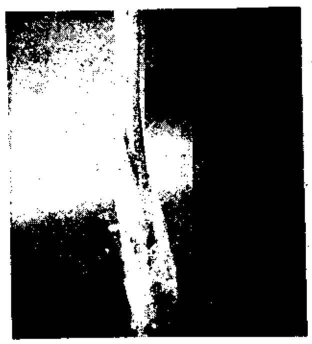
Fig. 3. Pycnidial formation

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Preliminary studies on the integrated management of castor grey mold under field conditions

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Abstract

Castor grey mold incited by *Botrytis ricini* Godfrey is the destructive disease causing considerable damage and reduces yield. A field experiment was conducted at Tapioca and Castor Research Station, Yethapur, Salem district, Tamil Nadu during *kharif* 2009-10 to find out the effective management measures for the control of grey mold of castor. Among seven treatments, carbendazim (0.1%) first spray on or before onset of disease appearance and second spray 10 days later is effective in reducing grey mold (11.8 PDI) and increased seed yield (2051 kg/ha) with a maximum B:C ratio (2.8). This was at par with *Trichoderma viride* (0.3%) first spray on before on set disease appearance and second spray 10 days later. Where as untreated control recorded maximum of 48.1 with lowest seed yield of 949 kg/ha.

Keywords: *Botrytis* grey mold, bio-control agents, castor, fungicides, field experiment, seed yield

Introduction

Castor (*Ricinus communis* L.) is mainly grown in *kharif* (Monsoon) season as a rainfed crop. It is considered to be a drought hardy crop and is cultivated during main growing seasons *viz., kharif* and *rabi* in India. It requires moderately high temperatures ranging from 20 to 26°C with low humidity and long, clear, sunny days throughout the growing period to produce maximum yield. Humid and cloudy weather during flowering period will promote fungal disease *viz., Botrytis*, resulting in loss of spike. Grey rot caused by *Botrytis ricini* is a serious air borne fungal disease especially under favourable weather conditions like continuous cloudy weather and high humidity.

Microorganisms used as bio-control agents are a possible alternative to fungicides *Trichoderma harzianum* was reported to suppress *Botrytis cinerea* in grapes (Dubos, 1984) and apple (Tronsmo, 1980) under field conditions. Apart from *Trichoderma* sp., *Pseudomonas fluorescens* also has been widely used in the management of diseases. Bio-control of *Botrytis* blight by *Psuedomonas* sp. has been reported on different crops. The use of *Trichoderma* (Boe *et al.*, 1998) and *Pseudomonas fluorescens* on different crops (Beastly *et al.*, 2001) in plant disease management has been well documented. Grey Mold (*Botrytis ricini*) appears on the castor raceme and capsule as a brown drop first, develops in to the white mycelium and turns grey resulting in dropping of flowers. Hence, the present study was undertaken to find out the effective management measures for the control of grey mold disease.

Materials and methods

A field experiment was conducted during *kharif* 2009-10 at Tapioca and Castor Research Station, Yethapur, Salem District, Tamil Nadu to find out the effective management measures for the control of grey mold disease in randomized block design with seven treatments which are replicated thrice in plot size of 5.4 m x 6.0 m. Castor variety (YRCH1) seed was sown in a spacing of 90 cm x 60 cm. Recommended agronomic practices were followed. Observations on grey mold incidence, number of capsule/spike, seed yield and 100 seed weight were recorded. B:C ration was also calculated. Data are statistically analyzed and presented in table 1.

Results and discussion

In the present investigation (Table 1), the results revealed that the minimum grey mold index (GMI) of 23.7 and 11.8 was recorded in the secondary and tertiary spikes respectively from the plots sprayed with carbendazim (0.1%) on or before disease appearance and second spray 10 days later followed by foliar spray with *Trichoderma viride* (0.3%) on before disease appearance and second spray 10 days later which recorded 23.7 and 14.8 PDI. The untreated control recorded the maximum of 80.3 and 48.1PDI in the secondary and tertiary spikes, respectively. Maximum number of spike/capsule

(36.2) was recorded in the primary spike from the plots sprayed with carbendazim (0.1%). Followed by the treatment with *Trichoderma viride* (0.3%) or which recorded 31.5. The untreated control recorded the minimum number of capsule/spike (13.3). Maximum 100 seed weight (34.3g) was recorded from the plots sprayed with carbendazim (0.1%), whereas untreated control recorded the minimum 100 seed weight (23.0). Foliar sprayed with carbendazim (0.1%) recorded the maximum seed yield of 2050 kg/ha with a B:C ratio of 2.8. This was on par with foliar sprayed with *Trichoderma viride* (0.3%) which recorded 1769 kg/ha with a B:C ratio of 2.7 whereas untreated control recorded minimum seed yield of 949 kg/ha.

In the present studies, foliar spray with carbendazim (0.1%) on or before disease appearance and second spray 10 days later was effective in reducing disease incidence and increasing seed yield. Foliar spray with *Trichoderma viride* (0.3%) on or before disease appearance and second spray 10 days later was also effective in reducing disease incidence and increased seed yield.

Similar findings were reported by Anonymous (2009) that two sprays of carbendazim (0.1%) recorded minimum (18.7%) *Botrytis* incidence and maximum seed yield (11.8 q/ha). Srinivasulu *et al.* (1994) tested six fungicides out of which maximum control was obtained with carbendazim. Madhu Meeta *et al.* (1986) and Rewal (1987) reported that spraying with carbendazim (0.1%) or carbendazim + thiophanate methyl (0.1%) significantly reduced grey mold intensity in chickpea. Depending on area cyclone warning centre's forecast, one spray of carbendazim/thiophanate methyl @ 1g/l before onset of cyclonic weather and one more spray after disease appearance were recommended as chemical control for castor grey mold (Anonymous, 2002). It may be concluded from the present studies that two sprays with carbendazim (0.1%) or *Trichoderma viride* (0.3%) are effective in increasing number of capsule/spike, 100 seed weight, the seed yield and decreasing the grey mold in castor.

Table 1 Management of *Botrytis* grey mold with chemicals and bio-control agents

Treatments	*Botrytis* grey mold incidence (%)			100 seed weight (g)	Yield (kg/ha)	B:C ratio
	Secondary spikes	Tertiary spikes	No. of capsules/spike			
Pseudomonas fluorescens (0.3%)	45.8	22.5	30.1	30.7	1743	2.6
Trichoderma viride (0.3%)	23.7	14.8	31.5	32.0	1769	2.7
Ethrel (50 ppm)	59.8	27.3	27.0	27.2	1410	2.2
Salicylic Acid (4 µl/l)	48.0	23.0	31.9	24.0	1487	2.4
Propiconazole (1ml/lit)	56.1	16.2	28.8	27.3	1509	2.3
Carbendazim (0.1%)	23.7	11.8	36.2	34.3	2051	2.8
Control	80.3	48.1	13.3	23.0	949	-
CD (P=0.05)	17.8	22.1	15.3	2.5	642	-

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RG 2787 : A multiple disease and nematode resistant castor germplasm accession

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Abstract

Wilt (*Fusarium oxysporum* f.sp. *ricini*), root rot (*Macrophomina phaseolina*), grey mold (*Botrytis ricini*) and reniform nematode (*Rotylenchulus reniformis*) are the major biotic stresses of castor (*Ricinus communis* L.). Chemical measures are not effective to control them. Growing resistant cultivar is an effective and environmental friendly approach. Castor germplasm accessions were screened under artificial epiphytotic conditions against wilt, root rot, grey mold and reniform nematode at multlocations in multi-years to identify resistant sources. The reaction of an accession, RG 2787 which exhibited stable multiple resistance to wilt, root rot, grey mold and reniform nematode was reported in the paper.

Keywords: *Botrytis*, castor germplasm, multiple resistance, reniform nematode, root rot, wilt

Introduction

Castor (*Ricinus communis* L.) is an important industrial oilseed crop grown across the world. India, China and Brazil are the major castor growing countries. Castor is vulnerable to many diseases and insect-pests. The major yield limiting diseases are wilt (*Fusarium oxysporum* f.sp. *ricini*), root rot (*Macrophomina phaseolina*) and grey mold (*Botrytis ricini*). Besides these diseases, reniform nematode (*Rotylenchulus reniformis*) is a severe pest in castor growing areas. It predisposes wilt and also individually causes injury to castor root. Growing resistant cultivars is an effective measure to manage them as chemical control is not effective. For development of any resistant cultivar, reliable base genetic material is crucial. Therefore, several castor germplasm accessions were screened against wilt, root rot, grey mold and nematode under artificial epihytotic conditions over years and locations. The reaction of one castor germplasm accession *viz.*, RG 2787, which consistently exhibited resistance to wilt, root rot, grey mold and nematode is disucssed in the present paper.

Materials and methods

Castor germplasm accession RG 2787 collected from Uranithan village, Villipuram district, Tamil Nadu was screened along with the susceptible check VP-1 against *Botrytis* grey mold under epiphytotic conditions in glasshouse for four years during 2003 to 2005 and 2006 to 2008 at the Directorate of Oilseeds Research, Hyderabad. Botrytis incidence was scored using 0-9 scale, where 0: no incidence, 1:1% of capsule infected, 3: 10% of capsules infected, 5: 11-25% capsules infected, 7: 26-50% capsules infected and 9: >50% capsules infected. Genotype having less than 10% infection was considered highly resistant.

RG 2787 was screened in wilt sick plots under All India Coordinated Research Project (AICRP) on Castor at DOR, Hyderabad and S. K. Nagar along with other test entries of AICRP during 2003-04, 2005-06, 2006-07 and 2007-08. The inoculum load was 2.3 x 10^3 cfu/g soil in wilt sick plots. Susceptible check planted in wilt sick plot was VP-1 in the first three years and JI-35 in the fourth year at DOR, Hyderabad and GAUCH-1 in the first year and JI-35 in other years at S.K. Nagar. Wilt incidence (%) was recorded at 30, 60, 90, 120, 150 and 180 days after sowing in wilt sick plots. Per cent wilt incidence was derived from the ratio of the number of diseased plants to the total number of plants. The scale proposed by Mayee and Datar (1986) was used to rate the reaction against wilt. The accessions showing less than 20% wilt incidence were rated as resistant.

RG 2787 and other germplasm accessions were screened against *Macrophomina* root rot under All India Coordinated Research Project (AICRP) on Castor at Junagadh in root rot sick plot for five years from 2003-04 to 2007-08 along with susceptible check GCH-4. Disease incidence was recorded from 90 to 200 days after planting. The accessions showing less than 20% root rot incidence were rated as resistant. RG 2787 was also screened against reniform nematode under artificial soil inoculation condition in pots for two years from 2004-2006. Female population/plant was counted; plants having 0 to 2 females/plant were categorized as resistant. Mean of 20 plants was taken for both the parameters.

Results and discussion

Grey mold caused by *Botrytis ricini* (Godfrey) becomes severe during cyclonic weather and can cause yield loss upto 85% (Raoof and Nageshwar Rao, 1999). It is a serious recurring problem in Andhra Pradesh and Tamil Nadu States of India. It affects capsule development and seed filling. Grey mold on castor appeared first time in epidemic condition in 1987 in Andhra Pradesh (Moses and Reddy, 1989). Since then it is reoccurring almost every year and causing sever damage. Non-genetic measures failed to control grey mold. Raoof and Mehatab Yasmeen (2006) confirmed host specificity of *B. ricini* to castor. All the existing castor varieties and hybrids are highly susceptible to grey mold. RG 2787 showed consistent resistant reaction against *Botrytis* in all four years of testing under artificial epiphytotic conditions. The disease infection was nil to 6.2% in RG 2787 whereas it was 82 to 100% in the susceptible check VP-1 (Table 1).

Wilt incidence up to 85% was reported in castor (Moshkin, 1986, Dange *et al.*, 1997). It can cause 39 to 77% yield loss depending on the stage at which the plants wilt (Pushpavati, 1995). Races of castor wilt are not yet reported. Wilt incidence in RG 2787 ranged from 5.8 to 17.6 % at DOR, Hyderabad and 0 to 10% at S.K. Nagar in wilt sick plots over years, whereas the disease incidence was 88 to 100% in susceptible checks (Table 2).

Root rot caused by *Macrophomina phaseolina* (Tassi) is one of the most serious diseases of castor. All the released cultivars are highly susceptible to root rot. Breeding for genetic resistance is needed to limit this disease. RG 2787 exhibited consistent resistant reaction against root rot under root rot sick conditions. The disease incidence was nil to 5.8% in RG 2787 over years while it was 72 to 87% in the susceptible check, GCH-4 (Table 3).

Reniform nematode is a severe constraint in most castor growing areas especially in the fields where monoculture of castor is taken up year after year. It principally spreads through cultivation and surface run-off or irrigation water. It takes about 19 days to complete life cycle on castor and multiplies several folds during crop period (Bishnoi and Yadav, 1989). Yield loss upto13.9% due to reniform nematode was reported (Jain *et al.*, 2007). Nematode causes both injury to roots as well predisposes wilt infection (Dange *et al.*, 2006). RG 2787 exhibited stable resistant reaction against reniform nematode in both the years under testing. It harboured very low number of females on its roots (0-1.3 females/plant) in pots whereas the susceptible entry had 10.3 to 10 females/plant (Table 4).

Multilocation-multiyear evaluation of RG 2787 under artificial conditions confirmed its stable resistant reaction against *Fusarium* wilt, *Macrophomina* root rot, *Botrytis* grey rot and reniform nematode. It would serve as reliable source in breeding programmes to introgress multiple resistance in elite backgrounds.

Table 1 Resistant reaction of RG 2787 against *Botrytis* grey mold

Year of screening	*Botrytis* infection (%)	
	RG 2787	VP-1(Susceptible check)
2003-04	0.0	82
2004-05	6.2	89
2006-07	2.9	100
2007-08	0.0	-

Table 2 Resistant reaction of RG 2787 against wilt

Year of screening	Wilt incidence (%) in wilt sick plots			
	DOR, Hyderabad		S.K. Nagar	
	RG 2787	Susceptible check	RG 2787	Susceptible check
2003-04	14.3	88 (VP-1)	0.0	98.5 (GAUCH-1)
2005-06	5.8	93 (VP-1)	0.0	100 (JI-35)
2006-07	17.6	100 (VP-1)	0.0	100 (JI-35)
2007-08	15.3	100 (JI-35)	10.0	100 (JI-35)

Table 3 Resistant reaction of RG 2787 against root rot

Year of screening	Root rot incidence at 200 days after planting in root rot sick plot (%)	
	RG 2787	GCH-4(Susceptible check)
2003-04	0.0	72
2004-05	0.0	85
2005-06	0.0	87
2006-07	5.8	84
2007-08	0.0	84

Table 4 Resistant reaction of RG 2787 against reniform nematode

Year of screening	Number of embedded females/plant	
	RG 2787	Susceptible check
2004-05	1.3	10.3
2005-06	0.0	10.0

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Identification of sources of resistance against *Fusarium* wilt in castor, *Ricinus communis* L.

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Abstract

A survey was conducted for assessing incidence and intensity of *Fusarium* wilt in major castor growing areas of Southern Telangana zone of A.P. *Fusarium* wilt incidence was observed to be ranged from 5 to 40%. Further, a field trial was conducted to evaluate 258 germplasm accessions in wilt sick plot. Initial inoculum load of the wilt pathogen was found to be 1.64×10^3 cfu/g of soil at the beginning of the experiment and it was increased to 1.83×10^3 cfu/g of soil. Out of 258 accessions screened, 27 germplasm accessions *viz.*, RG-1007, 1021, 1039, 1048, 1054, 1062, 1073, 1075, 1076, 1080, 1100, 1109, 1145, 1150, 1717, 1718, 1728, 1731, 1736, 1747, 1759, 1796, 1812, 1818, 1826, 1828, 1829, 1833, 1835, 1836, 1867, 1875, 1903, 1905, 1911, 1922, 1927, 1929 and 1938 were found to be resistant under wilt sick conditions.

Keywords: Castor *Fusarium* wilt, germplasm screening, survey

Introduction

Castor is the third important oilseed crop of Andhra Pradesh in acreage and economy after groundnut and Sunflower. The crop is mostly restricted to Southern Telangana agro-climatic zone of the state, in which Mahaboobnagar and Nalgonda districts account to 80% of total castor area of A.P. It is the livelihood crop of resource poor farmers in these two districts, which are characterized by low and erratic rainfall and shallow sandy soils. Castor is the most preferred crop in these areas as it is excellent rejuvenating capacity and genetic potential to give some yields in adverse conditions. In addition to growing of the crop completely under rainfed conditions, poor management and Fusarium wilt, a devastating disease are further depressing the yields up to 50% and worsening the precarious condition of the farmers.

Castor wilt caused by *Fusarium oxysporum* f. sp. *ricini* is one of the principal yield limiting factor in the production of castor in the major castor growing regions in India (Anonymous, 1998). The disease can be managed to a certain extent by fungicide seed treatment as well as with the use of biocontrol agents. Identifying resistant cultivars to these fungi in germplasm collection would be the most practical way to control the diseases. The present study was undertaken to identify source of resistance in castor germplasm for *Fusarium* wilt.

Materials and methods

Survey was conducted two times in the same fields during the crop season at 40 and 80 days after sowing. Intensity of the wilt was recorded on the basis of 100 plants selected randomly from each field. During the visit observations like location, soil type, irrigated/rainfed, previous crop grown, variety/hybrid, planting date, and disease incidence were recorded. Field screening was conducted during the year, 2007-08 in wilt sick plot of Regional Agricultural Research Station, Southern Telangana Zone of Andhara Pradesh, Palem, Mahaboobnagar district. Diversified types of castor germplasm accessions were obtained from Directorate of Oilseeds Research (DOR), Rajendranagar, Hyderabad. A total of 258 germplasm accessions were evaluated in highly wilt sick plot with Krathi as susceptible check and Haritha as resistant check. Germplasm accessions were sown in single row with 5m length with 45 cm x 30 cm spacing. Resistant and susceptible checks were sown after every 5 test entries. The inoculum load of the wilt pathogen was estimated before sowing and after harvest of the crop (Sharma and Singh, 1973) and expressed as cfu/g of soil. Inoculum load of sick plot was maintained by adding *Fusarium* culture multiplied on sorghum seeds at regular intervals and maintained through out the season. Disease incidence (number of infected plants) was monitored periodically at 30 days intervals up to 150 days. Wilt incidence was calculated using the formula.

$$\text{Wilt incidence} = \frac{\text{Number of plants showing wilt incidence}}{\text{Number of plants germinated}} \times 100$$

Germplasm accessions showing <20% wilt incidence were categorized as resistant and others as susceptible to this disease.

Results and discussion

Twenty one farmer's fields were surveyed for assessing incidence and intensity of wilt disease in major castor growing areas of Southern Telangana zone of A.P. Wilt incidence was ranged from 5 to 40% and presented in the table-1. In the beginning of the experiment initial inoculum load of the wilt pathogen in wilt sick plot was found to be 1.64 x 10^3 cfu/g of soil. Subsequently it was increased to 1.83 x 10^3 cfu/g of soil. No significant difference in the colony count was recorded at different locations of the plot. Out of 258 accessions screened, 39 germplasm accessions *viz.*, RG-1007, 1021, 1039, 1048, 1054, 1062, 1073, 1075, 1076, 1080, 1100, 1109, 1145, 1150, 1717, 1718, 1728, 1731, 1736, 1747, 1759, 1796, 1812, 1818, 1826, 1828, 1829, 1833, 1835, 1836, 1867, 1875, 1903, 1905, 1911, 1922, 1927, 1929 and 1938 were found to be resistant under highly wilt sick conditions up to 150 days after sowing. Wilt incidence in these accessions ranged from t to 20%, where as in the susceptible check Kranti it was 96.6% and 0% in the resistant check Haritha and all remaining accessions showed more than 20% wilt incidence and categorized as susceptible to the disease.

During survey it was observed that most of the farmers growing jowar, maize, redgram and castor as major crops in red *chlaka* soils under rainfed condition. In black cotton soils cotton is the major crop. Castor is grown mostly in red chalka soils under rainfed condition. Most of the farmers are sowing local varieties which are highly susceptible to Fusarium wilt and very low yielders. *Fusarium* wilt incidence as high as 85-90% was reported in wilt endemic areas of various castor growing states. Even the leading wilt resistant castor hybrid GCH-4 found to be susceptible to *Fusarium* wilt with 90% wilt incidence in endemic areas (Patel *et al.*, 1991). Hence there is a need for identification and incorporation of new source of wilt resistance in breeding material for development of resistant cultivars. It can be concluded that these resistant germplasm accessions identified can be used as donor parents in the breeding programme for the development of Fusarium wilt resistant variety in castor.

Table 1 Wilt incidence in rainfed castor crop in southern Telangana region

Location	Soil type	Previous crop	Variety/Hybrid	Disease incidence (%)
Khanpur	Red Chalka	Jowar	Kranti	23
Karukonda	Red Chalka	Castor	Kranti	25
Boyapur	Red Soils	Jowar	Haritha	5
Desitykyal	Red Chalka	Maize	Kranti	30
Peddakottapalli	Red Chalka	Castor	Local	40
Nallavelli	Red Chalka	Jowar	Kranti	28
Mahadevapeta	Red Soils	Maize	GCH-4	30
Sainpalli	Red Soils	Castor	Kranti	20
Mamaipally	Red Soils	Jowar	Navabharathi	20
Buddaram	Red Chalka	Maize	GCH-4	25
Tadiparti	Red Chalka	Redgram	Kranti	32
Palem		Jowar	Kranti	20
Vattem	Red Chalka	Jowar	Kranti	20
Vasantapur	Red Soils	Maize	Navabharathi	25
Wanaparthy	Red Chalka	Castor	GCH-4	30
Rajapur	Red Chalka	Maize	Local	24
Pebbair	Red Chalka	Jowar	Kranti	22
Bhoothpur	Red Chalka	Jowar	Local	30
Koszgi	Red Soils	Maize	Kranti	20
Kodangal	Red Soils	Redgram	Kranti	15
Chegunta	Red Soils	Jowar	Kranti	20

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Molecular analysis of genetic variability of various *Fusarium oxysporum* f.sp. *ricini* isolates by RAPD

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Abstract

DNA isolation and molecular analysis using Random Amplified Polymorphic DNA (RAPD) was done for fifteen isolates of *Fusarium oxysporum* f.sp *ricini* collected from castor wilt affected fields of Mahaboobnagar, Ranga Reddy and Hyderabad districts of Andhra Pradesh. The isolates were divided into two groups having two different sub clades with 65-100% similarity. The existence of low genetic variability among the isolates in this study is supported by the geographical proximity of locations of collection of the isolates.

Keywords: *Fusarium oxysporum* f.sp. *ricini*, molecular variability, RAPD markers

Introduction

In *Fusarium oxysporum* many formae specials (f.sp) and physiological races are known (Zeemankova and Ledbeba, 2001). Cultural, morphological and pathogenic variation observed in the isolates may not be only due to location but also due to cultivar used and environmental factors. Molecular studies at gene level with the help of polymorphic DNA technique like RAPD (Random Amplified Polymorphic DNA) is done to confirm and compare the variability in the isolates of *Fusariun oxysporum* f.sp. *ricini*.

Materials and methods

Five isolates of *Fusarium oxysporum* f.sp *ricini viz.*, For 61, 56, 57 (RARS Palem), For 63 (Boyapur) For 62 (Gudlanarva) collected from Mahaboobnagar, 7 isolates (For 74,75,77,70,79,68,78) from Ranga Reddy), three isolates (For 81,86,89) maintained at DOR are used for present study. These isolates were isolated on potato dextrose agar (PDA) and cultured on potato dextrose broth (PDB) for 3 days in incubator shaker. The mycelium obtained was harvested for DNA isolation. Genomic DNA was extracted by using the CTAB method (Lee and Taylor, 1990). The quality and quantity of DNA were assessed in agarose gel. Sixty random primers from OPA series (20 primers), OPE series (20 primers) and OPC (20 primers) were screened and amplification was observed with OPA 11 and 14 primers. The PCR amplification were carried out in a total reaction volume of 15µl containing 5-10 ng of genomic DNA. The PCR amplification were performed by using thermal cycler programmed for initial DNA denaturation for 4 minutes at 94°C, cyclic denaturation for 20 sec at 92°C, annealing for 0.45 sec at 36°C, extension for 2 minutes at 72°C and final extension for10 mts at 72°C. Likewise, 45 amplification cycles were completed in 3 hours and finally the temperature reaches 4°C. All the amplified DNA products were resolved by electrophoresis on agarose gel (1.4%) in TAE (0.5X) buffer, stained with ethidium bromide and photographed.

Statistical analysis: The binary data obtained was converted to NTEDIT data using NTSYS pc NTEDIT. Similarity values were generated among the isolates using the SIMQUAL function from the similarity tab and was used to generate dendogram by SHAN function using UPGMA analysis from clustering tab.

Results and discussion

This study demonstrates the genetic relatedness among the 15 isolates of *F. o* f.sp *ricini* using RAPD markers. Cluster analysis of binary data of the two RAPD primers generated a dendrogram that divided the isolates into two major groups (Group I and Group II) with percentage of similarity ranging from 65 to 100 among the isolates. Group I consists of 9 isolates (56, 75, 57, 61, 77, 78, 68, 70 and 62) which can be distinctly divided into two subclades designated as subclade 1 (56, 75 and 57 which were isolated from Mahaboobnagar district except For 75) and subclade-2 (61, 77, 78, 68, 70 and 62 which were isolated from Ranga Reddy district except For 61 and 62) with percentage of similarity ranging from 75.5 to 100% and 73 to 93%, respectively. The second group also consists of 6 isolates (63, 86, 79, 89, 81 and 74) that can also be distinctly divided into two subclades designated as subclade-1 (63, 86, and 79 which were from different districts) and sub clade-2 (89, 81 and 74 which were from Hyderabad district except For 74) with percentage of similarity ranging from 79.5 to 82% and 79.5 to 93%, respectively.

The results indicate overall low genetic variability among the *Fusarium oxysporum* f.sp. *ricini* isolates. Positive correlation was observed between the isolates in the groups with geographical origin except for For 74, 63, 86, 79, 61, 62, 75. The isolates (74, 63, 86, 79, 61, 62, 75) which are grouped in different subclades irrespective of their origin also shows low genetic diversity due to the closeness of the places from which they were isolated. This shows the isolates might not have aroused by evolutionary facts, rather it might be the part of ancestors. Exchange of contaminated seeds might have contributed to the low genetic diversity where this disease has been demonstrated as seed transmitted (Anonymous, 1986).

Table 1 Number of loci amplified by two RAPD primers in isolates of *Fusarium oxysporum* f.sp. *ricini*

Primers	Total number of bands	Polymorphic bands
OPA14	42	28
OPA11	61	5

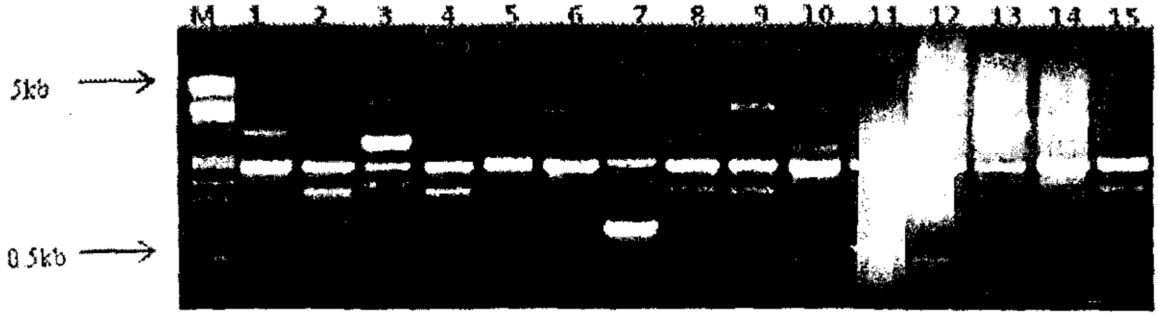

Fig. 1. Gel profile showing amplification of DNA of *Fusarium oxysporum* f.sp. *ricini* with OPA14 primer

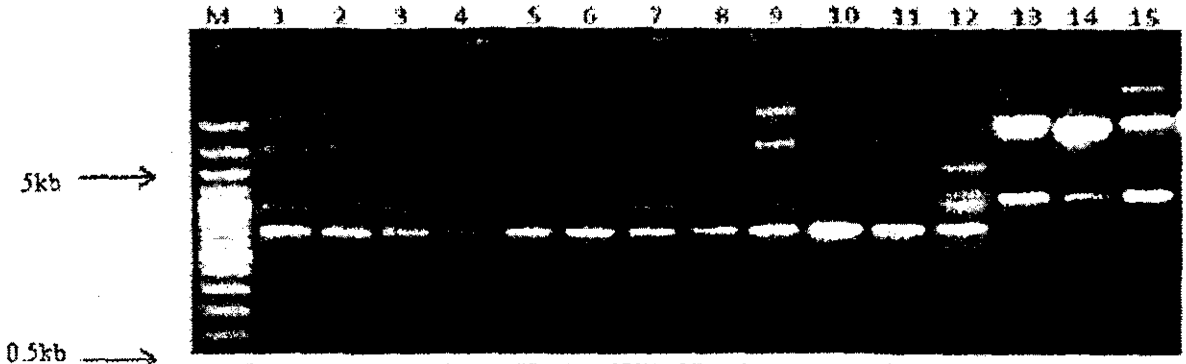

Fig. 2. Gel profile showing amplification of DNA of *Fusarium oxysporum* f.sp. *ricini* with OPA11 primer

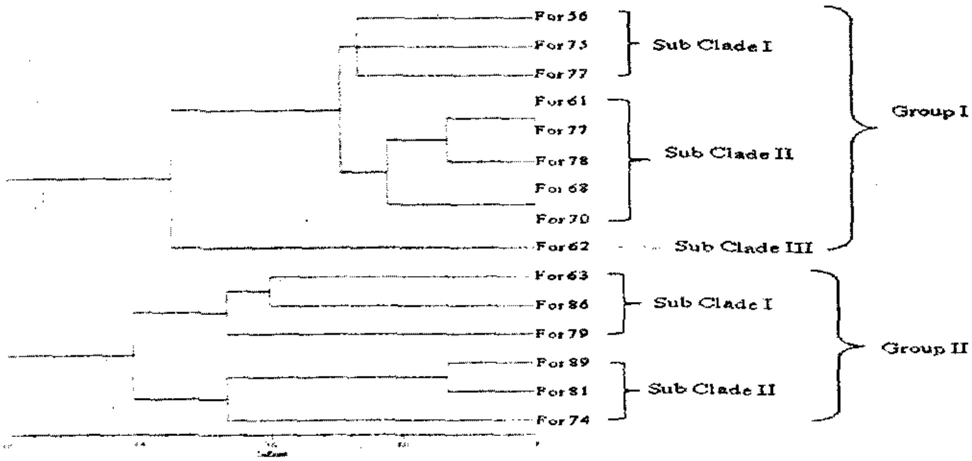

Fig. 3. Dendrogram derived from RAPD analysis of 15 isolates of *Fusarium oxysporum* f.sp. *ricini* by using 2 primers was constructed by using UPGMA analysis with NT-SYS pc software

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Morphological and cultural variation among isolates of *Alternaria ricini*

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Abstract

***Alternaria ricini* (Ar) was isolated from *Alternaria* leaf spot infected leaves of castor. The isolates were characterized for cultural and morphological variation on different media i.e., potato dextrose agar (PDA), potato carrot agar (PCA), malt yeast extract medium (MYEM), V_8 juice agar medium, skimmilk agar, castor leaf extract medium (CLEM) and Czapek's dox agar medium. Variation in mycelial growth and sporulation was observed on these media. Radial mycelial growth was more in castor leaf extract medium followed by skimmilk agar medium. The radial growth of all isolates ranged between 62 to 76mm on castor leaf extract medium. In other media it varied between 32.0 to 62.2 mm. The radial growth was fast in isolates Ar 5 and Ar 2, while it was slow in the Ar 3 on PDA. Ar 5, Ar 1 and Ar3 were recorded to be faster in growth on castor leaf extract medium and skimmilk agar. Sporulation was more on Czapek's dox agar medium while it was less in other media. Among the isolates, sporulation was more in Ar 5. In isolate Ar 3 the conidia were long, while in Ar 1 the conidia were short.**

Keywords: *Alternaria ricini*, cultural, castor, media, morphological characters

Introduction

Castor, *Ricinus communis* L., is one of the important oilseed crops in India and the oil is used for industrial purposes. Castor is known to be attacked by several pathogens at every stage of crop growth, which include mostly fungi and bacteria. In India, wilt, grey rot, seedling blight, root rot, *Alternaria* leaf spot and bacterial blights were recorded as important diseases on castor (Rangaswamy, 1979). *Alternaria* leaf spot in castor was first reported from Korea in 1929 (Yoshii, 1929) and in India it was reported from Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Rajasthan, Maharashtra and Tamil Nadu states. *Alternaria ricini* (Yoshii) Hansford causes seedling blight, leaf spot, inflorescence and pod rot of castor. All the aerial parts of the plant are affected but symptoms are more pronounced on leaves. In the seedling stage, light brown circular spots appear on cotyledonary leaves, which later become angular and coalesce to cause foliage blight. Severe infection results in death of the seedlings. On adult plants, brown, zonate, irregular spots of variable sizes with concentric rings surrounded by yellow halo appear scattered on leaves. In severe infection several spots coalesce to form big patches resulting in premature defoliation of the plant (Lakshminarayana and Raoof, 2005). Defoliation can be extensive. Under humid conditions, disease appears on inflorescence and capsules in the form of sooty growth. On shaking of infected spikes black clounds of spores are released (Stevenson, 1945). Such capsules are smaller in size and contain under developed or wrinkled seeds with little or no oil content. The fungus is seed-borne in nature. *A. ricini* is slow growing fungus hence different media were tested for the fast growth and heavy sporulation. Studies were conducted to find out the morphological and cultural variation in different isolates of *Alternaria ricini* and also growth of these isolates on different media.

Materials and methods

Leaf spot infected castor leaves were collected from different castor growing areas of Ranga Reddy district of Andhra Pradesh. *A. ricini* was isolated from these infected leaves and maintained on PDA slants for further studies.

Different solid media *viz.*, potato dextrose, potato carrot agar, malt yeast extract agar, V_8 juice agar, skimmilk agar, castor leaf extract medium and Czapek Dox agar medium were selected to observe cultural variability. Each of these sterilized media was poured separately in sterilized petri dishes and inoculated separately with 5 mm culture bits of each isolate. Inoculated petri dishes were incubated at 27±1°C and observation on mycelial growth was recorded after 5^{th}, 7^{th} and 9^{th} days of inoculation and sporulation was observed after 2 weeks.

To observe morphological variability, mycelial bit of 3 mm diameter was taken from 7-day-old culture of each isolate was transferred aseptically with the help of sterilized inoculation needle on to Czapek's dox agar medium. Three replications were maintained for each isolate. The inoculated petri dishes were incubated at 27±1°C. Spores collected from each isolate were stained with lacto phenol cotton blue and examined under microscope. For each isolate, sixty conidia were measured for their size, shape and septation.

Results and discussion

All the isolates produced maximum radial growth on castor leaf extract medium ranging from 62.0 (Ar 2) to 76.0 mm (Ar 5) followed by skimmilk agar medium (Table 1). Minimum radial growth was observed in V_8 juice agar medium (32 mm) followed by PDA (34 mm) and Czapek's dox medium (35 mm). Bardia *et al.* (2008) observed cultural and morphological variability among six *Fusarium oxysporum* isolates on ten different solid media. All the isolates of *F. oxysporum* produced maximum radial growth on Czapek dox agar medium ranging from 7.2 cm (isolate A2) to 9.0 cm (isolate A4) followed by PDA medium. Minimum radial growth was observed in Asthana Hawker's medium followed by Broun's medium.

Sporulation was slow in *A. ricini*, it starts sporulating 10 days of inoculation, hence sporulation was recorded 2 weeks after inoculation. *A. ricini* isolates sporulated heavily on Czapek's dox agar media and it was less on other media like potato dextrose agar, Potato carrot agar, malt yeast extract agar, skimmilk agar, castor leaf extract medium and V_8 juice agar. Maximum sporulation was observed in Ar 5 and minimum in Ar 2. Kumar *et al.* (2008) studied cultural and morphological variation of eleven *Alternaria solani* isolates on four selected media and observed fastest radial growth in Dh, Ba-1 and Va-3 of isolates on *Alternaria* sporulation medium followed by V_8 juice agar while fastest radial growth was recorded in the So isolate and slowest in the Ka isolate on PDA. Sporulation was not found in any of the *A. solani* isolates on four different media.

Table 1 Cultural variation among *A. ricini* isolates

Isolate	Growth on media (mm)							
	PDA	PCA	MYEA	V8 juice agar	Skimmilk agar	CLEM	Czepek's dox agar	AVG
Ar 1	45.0	57.0	52.0	41.0	56.0	72.0	42.0	52.1
Ar 2	49.0	47.0	60.0	40.0	50.0	62.0	35.0	49.0
Ar 3	34.0	55.0	50.0	40.0	58.0	69.0	49.0	50.7
Ar 4	43.2	50.0	48.0	32.0	62.0	64.3	40.0	42.0
Ar 5	49.4	52.0	50.0	49.0	62.2	76.0	48.3	55.2

Typical spores of *Alternaria* species were observed and these are obclavate in shape, light olive in colour become darker in mass. They are segmented into 5-12 cells with transverse and longitudinal septa with beak. The beak is narrow, colorless, long and unbranched. Ar 3 showed long condia with measurements of 106.4 x 26.6µm with more septa (Table 2). In Ar 2 the condia were small (79.8 x 15.2µm) with less septa. Hence the studies revealed that castor leaf extract medium is the best medium for the vegetative growth while Czapek's dox agar medium is suitable for heavy sporulation of *A. ricini*.

Table 2 Morphological variation among *A. ricini* isolates

Isolate	Length (µm)	Width (µm)	Septa
Ar 1	83.6	19.0	6
Ar 2	79.8	15.2	4
Ar 3	106.4	26.6	12
Ar 4	91.2	19.0	8
Ar 5	79.8	22.8	6

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Selection of castor germplasm as resistance sources to *Fusarium oxysporum* f. sp. *ricini*

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Abstract

For the selection of castor germplasm lines resistant to *Fusarium oxysporum* f. sp. *ricini*, 20 accessions were screened with JI-35 as susceptible and 48-1 as resistant checks by root dip inoculation technique under green house conditions. Six germplasm accessions *viz.*, RG-1631, RG-2090, RG-2661, RG-2746, RG-3100 and RG-3105 were found resistant (< 20 % wilt), whereas one accession RG-1929 was moderately resistant (30 % wilt) to *Fusarium* wilt of castor. Three germplasm accessions *viz.*, RG-2479, RG-2606 and RG-3098 were found moderately

susceptible (>40 - 60 % wilt) and remaining ten lines were susceptible (65.0 to 95.0% wilt incidence) to the disease. The identified germplasm that are resistant to *Fusarium* wilt pathogen could be used in breeding programme to incorporate resistance in to agronomically superior backgrounds to develop high yielding resistant varieties/hybrids.

Keywords: Castor, *Fusarium* wilt, resistance sources

Introduction

Castor (*Ricinus communis* L.) is an important non-edible crop of arid and semi-arid regions of India. The crop is largely grown in Gujarat, Andhra Pradesh, Rajasthan, Tamil Nadu, Karnataka and Orissa. Wilt in castor is caused by *Fusarium oxysporum* f. sp. *ricini* Nanda and Prasad is one of the principal yield limiting factor in the production of castor in the major castor growing regions in the country. As the wilt of castor is primarily soil-borne, it becomes difficult to manage the disease through chemical or physical means. Resistant varieties / hybrids is the best and cheapest method to manage the disease. The effectiveness of a host-plant resistance in breeding programme largely depends on identification of resistance sources. Selection of breeding procedures aims to incorporate resistance in to agronomically superior backgrounds to develop high yielding resistant varieties/hybrids.

Materials and methods

For the identification of resistance sources against *F. oxysporum* f. sp. *ricini*, 20 castor germplasm accessions were screened with JI-35 as susceptible and 48-1 as resistant checks by root dip inoculation technique under green house conditions (Desai and Dange, 2003). Twenty seedlings were used for each germplasm accession. The seeds of each germplasm accessions were surface sterilized separately with 2.5% sodium hypochlorite solution for five minutes and then sown in autoclaved riverbed sand filled in plastic trays for raising the seedlings. The trays were watered as and when needed. The inoculum of the pathogen was prepared by multiplying the fungus on sorghum grain medium (sorghum grains were soaked in 2% sucrose solution overnight and then 100 g sorghum grains were autoclaved in 250 ml conical flask) by putting aseptically mycelial disc cut from the periphery of seven days old culture of the fungus grown on PDA medium. The flasks were inoculated at 27±2°C temperature for 10 days. The spore suspension was prepared by transferring the sorghum medium with sporulating fungus in to distilled water, stirred well and filtered through double layered muslin cloth. The concentration of the spore suspension was adjusted to 1×10^6 spores/ml with the help of haemocytometer.

Ten days old seedlings of individual germplasm accession grown in the riverbed sand were uprooted, washed in running tap water, then clipped from distal one-third root system and dipped for one minute in the fungal spore suspension (1×10^6 spores/ml). Inoculated seedlings were transplanted in the earthen pots (30 cm diameter) filled with autoclaved soil. Twenty seedlings were maintained for each germplasm accession. The pots were watered as and when needed. The observations on wilt incidence were recorded periodically up to 30 days after transplanting.

Results and discussion

Twenty accessions of castor germplasm were screened by root dip inoculation technique under green house conditions for selection of resistant sources to wilt. Only six germplasm accessions *viz*., RG-1631, RG-2090, RG-2661, RG-2746, RG-3100 and RG-3105 were found resistant (<20% wilt), whereas one accession RG-1929 was moderately resistant (30% wilt) to *Fusarium* wilt disease. Three germplasm accessions *viz*., RG- 2479, RG-2606 and RG-3098 were found moderately susceptible (>40-60 % wilt) and remaining ten were susceptible (65.0 to 95.0% wilt) to the disease (Table 1). The known susceptible check JI-35 and resistant check 48-1 showed highly susceptible and resistant reaction, respectively to *F. oxysporum* f.sp. *ricini*. Root dip inoculation technique has been tried in muskmelon (Latin and Snell,1986), watermelon (Zhang *et al*., 1991), pigeonpea (Haware and Nene, 1994) and castor (Raoof and Rao, 1996) for the identification of resistance materials to *Fusarium* wilt disease. The root dip inoculation technique is more efficient, quicker and reliable to screen the castor germplasm and breeding materials against *Fusarium* wilt disease for early detection of resistance sources in pot study. In the present study, six germplasm accessions *viz*., RG-1631, RG-2090, RG-2661, RG-2746, RG-3100 and RG-3105 were identified as resistance sources to *Fusarium* wilt pathogen which could be used in breeding programme to incorporate resistance in to agronomically superior backgrounds to develop high yielding resistant varieties/hybrids.

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Table 1 Reaction of castor germplasm accessions to *F. oxysporum* f.sp. *ricini*

Germplasm accession	Total plant stand	Wilt (%)30 DATP	Disease reaction
RG-157	20	65.0	S
RG-256	15	70.0	S
RG-269	14	92.9	S
RG-430	18	77.8	S
RG-737	15	70.0	S
RG-880	19	89.5	S
RG-1076	19	65.8	S
RG-1631	20	17.5	R
RG-1929	20	30.0	MR
RG-2090	20	20.0	R
RG-2284	20	95.0	S
RG- 2469	20	92.5	S
RG-2479	20	55.0	MS
RG2606	18	52.8	MS
RG-2661	17	17.6	R
RG-2746	20	00.0	R
RG-2891	20	72.5	S
RG-3098	19	47.4	MS
RG-3100	18	16.7	R
RG-3105	19	00.0	R
48-1 (R) ©	20	00.0	R
JI-35 (S) ©	20	100.0	S

© Check; R=<20% wilt; MR=>20-40% wilt; MS=>40-60% wilt; S=>60% wilt

Salient features of castor genotype RG 2824 suiting ericulture in West Bengal

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Abstract

Ericulture is rearing of semi- domesticated eri silkworm (*Samia ricini* Donovan. Saturniidae: Lepedoptera), predominantly with castor (*Ricinus communis* L. Euphorbiaceae) leaves, spinning of eri cocoons and weaving of endi fabric. It is progressing in steady stride in ericulturally non-traditional West Bengal. The dearth of organized castor cultivation in the state led to evaluate the castor genotype RG 2824 as one of the suitable hosts for ericulture in the region.

Keywords: Castor, ericultre.

Introduction

Sericultural distinctiveness of India encompasses production of all four commercially exploited natural silks. They are mulberry and *Vanya* silks namely Eri, Tassar and Muga. Eri silk accounts for 11% of the total raw silk produced in India.

Sericulture in India has a labour-intensive agricultural pattern with traditional strengths. It has capabilities of generating income along the entire value chain starting from cultivation of hosts till the production of the finished product. The eri sector of sericulture was confined to the North-East and congruent Eastern India till 3 decades ago. But it is identified as a vocation for rural reconstruction in some non-traditional areas since it involves low investment and high output source of employment and income. Eri silk is unique in having the texture of natural silks, thermal quality of wool and feel of cotton. Ericulture is maintenance or sourcing of leaves of food plants, rearing of eri silkworm and spinning and weaving of endi fabrics. Eri silkworm (*Samia ricini* Donovan; Saturniidae: Lepidoptera) is exception to *Vanya* silks as these can be reared indoor throughout the year. It is polyvoltine producing white, yellowish or brick-red one or both sides open ended cocoons.

Though it is polyphagous rearing with leaves of primary host castor (*Ricinus communis* L. :Euphorbiaceae) scores the best cocoon harvest (Sarkar, 1980; Benchamin and Jolly, 1987). In India more than 90% of the eri silk is castor-based and about

98% of castor plants utilized in ericulture belongs to naturally thriving flora of the region (De and Das, 2007). The capacity of castor to grow on diverse range of soils and of becoming excessively luxuriant with increase of soil moisture opens up the vista for large scale extension of ericulture as it is found to thrive almost all over India. It can act as an antidote to a great extent in providing income to the rural or semi-urban landless workforce who utilizes locally grown castor plants for rearing throughout the year (Singh and Benchamin, 2002; Bindroo *et al.*, 2007). Presently it is practiced in 16 Indian states and West Bengal occupies the 6th position in total eri silk produced in India. In West Bengal ericulture is exclusively castor-based and practiced in 3 districts, *viz.*, Jalpaiguri, South Dinajpur and South 24 Parganas.

Most of the eri farmers in the state belongs to below poverty line category. Since castor is not a cultivated oil seed crop in West Bengal, in absence of any recommended variety/genotype, the eri farmers depend mostly on either natural castor flora at the vicinity or indiscriminately raised castor plants from annuals (Chaudhuri *et al.*, 2009). Systematizing the castor food plant sector was acutely felt by both central and state sectors. Consequently, 84 castor genotypes were collected from the Directorate of Oilseeds Research, Hyderabad, Central Muga and Eri Research and Training Institute, Lahdoigarh, Assam and locally available flora and screened at Central Sericultural Research and Training Institute, Berhampore, West Bengal (88°15'E : 24°6'N; 19 m. MSL). The screening led short listing of 10 promising castor genotypes on the basis of leaf yield and standard growth parameters. The genotype RG 2824, collected from DOR Hyderabad was identified as the best food plant for eri silkworm rearing at the test location (Chakravarty, 2008).

Materials and methods

RG 2824 was grown annually in 3 replications for 4 consecutive years since 2006-07, the planting season being March. Primary data on per plant basis were recorded on leaf yield and associated growth parameters coinciding with eri silkworm crop rearing seasons in June, August, September, November and February. Summary statistics of growth and yield data have been worked out. Rearing was conducted in 3 replications with yellow marked strain of eri silkworm by feeding RG 2824 leaf lamina for 1 year during 2009-10. The 5 most important growth parameters namely (1) height up to primary raceme in cm, (2) mean height in cm, (3) number of nodes, (4) Number of branches and (5) leaf petiole yield in g were regressed over lamina yield in g to ascertain the impact of independent variables upon the economic yield (Table 1).

Results and discussion

Almost all the growth and leaf yield traits showed wide variability under seasonal influence as reflected in table 1. Height up to primary raceme increased with age. Mean height appeared to be disrupted after first harvest but picked up during September harvest, again to fall in November. Then left undisturbed, it reached the highest in February. Number of nodes increased with passage of time till monsoon harvest, plummeting during dry and cold months. The trait of number of branches varied very little through out the year. Petiole yield increased steadily till September and then decreased through November and February harvests. But maximum petiole yield was recorded during February. Mean lamina yield increased after the first harvest in August and decreased steadily then onwards, though highest leaf harvest was observed after monsoon in September. The highest leaf harvest might have been attributed by increased soil moisture in monsoon resulting in vegetative luxuriance.

Table 1 Summary statistics of growth and yield data of RG 2824

Crop		Trait					
		Height upto primary raceme (cm)	Mean height (cm)	Number of nodes	Number of branches	Leaf petiole yield (g)	Lamina yield (g)
Jun	Mean	150.00	409.79	10.83	6.33	229.00	518.07
	SD±	16.76	63.61	6.77	0.50	114.98	56.12
	Min.	121.00	324.00	6.00	6.00	85.00	425.00
	Max.	174.00	510.33	20.50	7.00	363.00	613.00
Aug	Mean	172.00	338.20	23.11	5.00	288.33	570.44
	SD±	34.55	116.48	2.57	0.75	55.16	93.47
	Min.	141.00	178.00	19.00	4.00	228.00	430.00
	Max.	220.00	464.80	27.00	6.00	380.00	720.00
Sep	Mean	181.44	481.11	41.94	6.22	300.28	564.89
	SD±	32.70	42.88	16.30	1.56	118.85	157.22
	Min.	141.00	388.00	19.00	4.00	168.33	403.33
	Max.	220.00	524.00	59.00	8.00	526.67	916.67
Nov	Mean	269.77	333.44	32.89	5.78	275.11	333.06
	SD±	109.74	135.60	18.88	-	126.07	192.30
	Min.	21.00	142.00	19.00	4.00	138.00	173.00
	Max.	396.00	514.00	59.00	7.00	440.00	616.67
Feb	Mean	345.44	404.13	30.03	5.85	229.56	346.56
	SD±	78.19	177.64	8.41	0.60	233.91	85.64
	Min.	208.80	159.00	19.00	5.00	68.00	218.00
	Max.	422.00	561.00	40.00	7.00	571.00	418.33

Yellow marked eri silkworm was reared with RG 2824 during 2009 and important economic parameters are enumerated in table 2. Rearing performance was superior during Sept.-Oct. and Feb.-March crops pertaining to fecundity, single cocoon weight in g, single cocoon weight in g, cocoon yield/disease free laying reared and shell %. This corroborates the earlier finding by Chakravarty (2009).

The multiple regression analysis elucidates strong association of leaf lamina yield with most of the 5 yield attributing traits as indicated by high multiple correlation (R=0.80). The regression equation led to comprehension that with increase in petiole yield, mean height, number of nodes and decrease in number of branches and height up to primary raceme, lamina yield will increase (Table 3). All the regression coefficients except that for the number of branches have significant contribution towards lamina yield. Moderately high coefficient of determination (R^2=0.66), low residual and highly significant F value justifies the fitness of the regression model. The portion of 39% variability (1.-R^2) may be ascribed to the crop management, castor plant system biology coupled with prevailing biotic and abiotic factors.

Further study still in progress reveals that RG 2824 has survived pruning at 1m height after attaining 1 year of age in March. 2010 and put forth a number of effective branches with profused leaves, a character keenly sought by the eri-farmers in West Benagal.

Table 2 Eri silkworm rearing performance with RG 2824

	Fecundity	*Single cocoon weight (g)*	SSW	*Cocoon yield/disease free laying reared*	Shell (%)
Jun	378	2.7	0.37	281	13.70
Jul-Aug	294	2.65	0.36	212	13.58
Sep-Oct	392	2.9	0.41	313	14.14
Nov-Dec	360	2.69	0.37	277	13.75
Feb-Mar	352	2.73	0.39	269	14.29

Tabled 3 Results of multiple regression analysis

	df	SS	MS	F
Regression	5	761503.63	152300.73	15.47**
Residual	39	383884.44	9843.19	
Total	44	1145388.07		

R=0.82; R^2=0.66; Regression equation: lamina yield = 7.97+ 1.15 x petiole yield + 0.55 x mean height + 0.69 x No. of nodes -1.60 x No. of branches - 0.32 x height upto primary raceme

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Reaction of castor cultivars against whitefly, *Trialeurodes ricini* Misra

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Abstract

A field trial was conducted to screen out of released varieties of castor against whitefly (*Trialeurodes ricini* Misra). During the screening, none of the lines were found free from the attack of whitefly. Population of whitefly ranged from 4 to 110 adults/plant. Out of thirty lines tested for resistance to whitefly, minimum population was recorded

in PCH-234 (4 whitefly adult/plant). It was followed by JC-10 (5 whitefly adults/plant), DCH-177 (6 whitefly adult/plant) and JC-12 (6 whitefly adult/plant). Two lines *viz.*, RHC-199 and DCS-105 found moderately resistance to whitefly. RHC-277 found highly susceptible recording 110 whitefly adults/plant.

Keywords: Castor, reaction, whitefly, *Trialeurodes ricini* Misra

Introduction

Castor is one of the important crop which is extensively cultivated in northern parts of the Gujarat state. Now-a-days, large number of castor varieties are grown in castor growing areas of Gujarat state. Owing to extensive cultivation of castor under high inputs, pest problems increased tremendously. Recently, white fly gained status of key pests of castor in Gujarat state. Considering the disadvantage of synthetic chemicals, development of resistant varieties against whitefly is very important. Keeping this view in mind, attempt was made to screen castor varieties against whitefly.

Materials and methods

A field trial of 30 elite entries of castor was conducted at Main Castor and Mustard Research Station, S.D. agricultural University, Sardarkrushinagar during 2009-10. All entries were grown under unsprayed conditions. Entries were sown with the spacing of 90 cm x 60 cm in plot size of 6 m x 4.5 m. All the recommended package of practices was followed for raising a good crop except spraying of insecticides. Observations on population of whitefly was recorded from top leaves of three randomly selected and tagged plants at 80, 120 and 150 days after sowing (DAS). Out of three observation, maximum population of whitefly was considered and presented in table 1.

Results and discussion

Out of 30 entries tested for resistance to whitefly, minimum population was recorded in PCH-234 (4 whitefly adult/plant). It was followed by JC-10 (5 whitefly adults/plant) and DCH-177 (6 whitefly adult/plant) and JC-12 (6 whitefly adult/plant). Two entries viz.., RHC-199 and DCS-105 were found moderately resistance to whitefly recording 9 and 10 whitefly adults/plant, respectively. RHC-277 found highly susceptible with 110 whitefly adults/plant. It was followed by MCI-9 (91 whitefly adults/plant). Similar findings were also reported recently (Anonymous, 2010). It is concluded that entries *viz.*, PCH-234, JC-10 and DCH-177 may be used for further breeding programme to develop to resistance/tolerant varieties against whitefly.

Table 1 Testing of different entries of castor for resistance to whitefly at S.K. Nagar during 2009-10

Entry	Whitefly adults/plant	Entry	Whitefly adults/plant
MCI-8	42	JHB-968	65
JC-1	27	RHC-277	110
DCS-105	10	SHB-864	73
JC-2	45	SHB-872	37
DCS-106	30	SHB-873	39
DSP-222	46	48-1	29
DCS-107	26	DCS-9	19
RHC-199	9	SKI-332	45
JHB-958	35	SKI-338	45
GCH-7	41	JI-368	84
DCH-177	6	MCI-9	91
DCH-519	34	JC-8	75
PCH-234	4	MCI-10	49
PCH-244	59	JC-10	5
NBCH-11662	47	JC-12	6

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Management of defoliators in hybrid castor for north western zone of Tamil Nadu

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Abstract

Studies on the management of castor defoliators *viz.*, *Sprodoptera*, semilooper and hairy caterpillars on castor hybrid TMVCH - 1 over two years (2008 - 09 and 2009 - 10) revealed mechanical control of defoliators has resulted with a higher seed yield of 819 kg/ha with a B:C ratio of 1.79 when compared with 513 kg/ha in the untreated.

Keywords: Castor, defoliators

Introduction

In castor growing areas of Tamil Nadu, among the defoliators outbreak of *Spodoptera litura* (fab.) is most common and severe during October to December with heavy defoliation. During November to January semilooper, *Achaea Janata* and hairy caterpillars *Euproctis fraterna* and *Spilosoma oblique* cause severe defoliation resulting in seed yield loss. To manage the defoliators in hybrid castor, timely management practices involving cost effective, environmentally safe natural enemies prevalence and eco-friendly approaches are highly essential for obtaining a profitable castor seed yield. Hence, this study was undertaken at Tapioca and Castor Research Station, TNAU, Yethapur.

Materials and methods

To evaluate the different management practice against castor defoliators *viz.*, tobacco caterpillar, semilooper and hairy caterpillars, field experiments were conducted at Tapioca and Castor Research Station, Yethapur during two rainy seasons (2008 and 2009) under rainfed situation. Castor crop was grown with a spacing of 90 cm x 60 cm (row to row and plant to plant). Five treatments *viz.*, erecting bird perches @ 25/ha, mechanical control, Monocrotophos 36 wsc 0.05%, mechanical control of defoliators + Monocrotophos 36 wsc 0.05% and untreated control were imposed. Based on the rains, recommended dose of fertilizers and proper plant stand was maintained. Each treatment was conducted in a macroplot of 700 m^2 under non - replicated condition.

Defoliator treatments were given when about 25% defoliation due to defoliators was observed during vegetative, flowering and spike initiation stages on hybrid castor crop TMVCH-1 under rainfed conditions. The treatments were given two times at 15 days interval. Larval population of defoliation/plant and % defoliation at 7 days before and after treatment on twenty plants was observed and the mean incidence of larval population and defoliation were worked out. Natural enemies on defoliators were also recorded simultaneously.

Results and discussion

The pooled analysis of the two years mechanical control of defoliators has resulted with a higher seed yield of 819 kg/ha with a B:C ratio of 1.79 when compared with 513 kg/ha in the untreated (Table 1). In plots of bird perches erection the management cost is very low since placement of sticks above the crop height @ 25/ha helps the Drongo bird to sit and predate the defoliators with a satisfactory B:C ratio of 1.52 along with natural enemy prevalence in the treatment.

Hence, this type of managing the defoliators damage <10% and the natural parasitisation by *Cotesia* sp *Spodoptera* and hairy caterpillars and *Microplitis* sp on semilooper will give a better net return to the Tamil Nadu castor growers.

Table 1 Management of defoliators in castor

Treatment	Pooled analysis (2008-09 and 2009-10)								
	Population of defoliators (No/plant)						Larval parasitisation (%)*	Seed yield (kg/ha)	B:C ratio
	Achaea janata		*Spodoptera litura*		Hairy caterpillar				
	PTC**	7 DAT	PTC	7 DAT	PTC	7 DAT			
T_1 : Erecting bird perches @ 25 nos/ha	2.5	1.5	8.2	7.2	2.0	1.5	4.1	666	1.52
T_2 : Mechanical control of defoliators	2.2	0.35	11.9	0.85	2.5	0.6	3.2	819	1.79
T_3 : Monocrotophos 0.05%	1.4	0.0	10.6	6.1	2.8	0.55	0.0	831	1.75
T_4 : Mechanical control + monocrotophos 0.05%	1.5	0.0	11.6	0.3	2.8	0.35	0.0	840	1.71
T_5 : Untreated control	2.5	2.0	9.6	11.9	3.8	3.95	4.3	513	-

LP * = *Cotesia* sp. on *Spodoptera* 6.3%; LP ** = *Microplitis* sp. on Semilooper 8.1%; PTC = Pre-treatment count

Bio-efficacy of some chemical insecticides and bio-pesticides against capsule borer, *Conogethes punctiferalis* (Guen.) in castor

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Abstract

Field experiment was conducted with eight treatments *viz.*, Carbaryl 50 WDP @ 0.2%, Endosulfan 35 EC @ 0.05%, Triazophos 40 EC @ 0.05%, Spinosad 45 SC @ 0.018%, Fipronil 5 SC @ 0.01%, Neem Seed Extract @ 5% (w/v), *Bacillus thuringiensis* @ 0.1% and Untreated control for the control of castor capsule borer, *Conogethes punctiferalis* (Guen.) on cultivar DCS-9 during the rainy season of 2009. The spray fluid @ 500 l/ha was used in each of the treatment. Two sprays of all the treatments except untreated control were applied at 45 and 60 days after sowing (DAS). The treatment with 0.2% Carbaryl was the most effective in suppressing capsule borer incidence and produced higher seed yield (801 kg/ha) with higher B:C ratio (1.46) followed by 0.02% Fipronil (605 kg/ha) with B:C ratio of 1.13. The other treatments were found relatively less effective for the control of capsule borer.

Keywords: Castor capsule borer, insecticides, bio-pesticides

Introduction

Castor (*Ricinus communis* L.) is an important industrial and commercial oilseed crop of arid and semiarid tropics of the world. The total castor seed and oil production of the world is 13.27 lakh m.t. and 5.47 lakh m.t., respectively. In India, it is grown mainly under rainfed condition over an area of 7.13 lakh ha with annual production of 8.5 and 3.36 lakh m.t. castor seeds and oil, respectively which accounts for 53% of area and 70% production of the world. The crop is infested with a number of insect pests. The most important ones are the defoliators *viz.*, semilooper (*Achoea janata* L.) and tobacco caterpillar (*Spodoptera litura* F.) and the capsule borer *Conogethes punctiferalis* (Guen.) (Lakshminarayana and Raoof, 2005). In general, all the released castor varieties and hybrids are found to be susceptible to the capsule borer. Yield loss of 19 and 85% has been reported due to semilooper and capsule borer, respectively (Singh *et al.*, 1992). The capsule borer attacks castor crop from flowering stage onwards with a characteristic webbing of capsule along with excreta and frass. Thus, the capsule borer which was at low key in the past is becoming more serious in recent years causing 20-50% capsule damage in the country. In the present investigation, the efficacy of some chemical insecticides and bio-pesticides against capsule borer in castor were evaluated.

Materials and methods

The field experiment was conducted at Zonal Agricultural Research Station, MPKV, Solapur during the rainy season of 2009 with eight treatments including absolute control in randomized block design (Table 1). The cultivar DCS-9 was sown in the plots of 3.80 x 5.40 m^2 at 90 cm x 30 cm spacing with three replications. Two pesticide sprays were given at 45 and 60 days after sowing (DAS). All the recommended agronomic practices were followed uniformly in each plot. The observations on capsule damage i.e. average % infestation due to capsule borer in each treatment and seed yield at harvest were recorded and analyzed. The % infestation reduction over control and economics of the treatment were also ascertained.

Results and discussion

The results revealed the significant differences among the treatments studied in both % infestation and seed yield at harvest (Table 1). However, significantly highest capsule damage (43.7%) was recorded in absolute control over rest of the treatments. Among the treatments, 50 WDP Carbaryl @ 0.2% recorded the minimum capsule damage (13.22 %), which was however statistically at par with 5 SC Fipronil @ 0.02% (16.32%), 45 SC Spinosad @ 0.018% (22.06%), *Bacillus thuringiensis* @ 0.1% (23.81%), 35 EC Endosulfan @ 0.05% (24.07%) and 40 EC Triazophos @ 0.05% (24.50%). So also, the maximum % reduction infestation over control was noticed in 50 WDP Carbaryl @ 0.2% (69.77%) followed by 5 SC Fipronil @ 0.02% (62.68%) and 45 SC Spinosad @ 0.018% (49.55%).

As regards seed yield, significantly highest seed yield of 801 kg/ha was produced by Carbaryl 0.2% followed by Spinosad 0.018% (619 kg/ha), Fipronil 0.02% (605 kg/ha) and NSE 5% (546 kg/ha). These four treatments were statistically at par with each other in respect of seed yield. The highest B:C ratio of 1.46 was recorded by Carbaryl 0.2% followed by Fipronil 0.02% (1.13). Rest of the treatments were economically ineffective. Significant yield losses due to capsule borer were reported (Anonymous, 2006). The effectiveness and economics of Endosulfan and Monocrotophos against castor capsule borer was reported by earlier workers (Patel *et al.*, 1987; Geetha *et al.*, 2003). However, neem seed extract (5% was not found effective in reducing capsule borer infestation (Anonymous, 2006) which is in agreement with the present findings. Singh and Kanujia (2003) also reported neem seed extract to be less effective against the castor defoliators.

Overall results indicated that the two sprays of 0.2% Carbaryl 50 WDP or 0.02% Fipronil 5 SC at 45 DAS and second at 60 DAS were found effective and economical for the control of castor capsule borer and increasing the seed yield of castor.

Table 1 Efficacy of pesticides for the control of capsule borer

Treatment	Infestation due to capsule borer (%)	Infestation reduction over control (%)	Seed yield (kg/ha)	B:C ratio
Carbaryl (Sevin) 50 WP 0.2%	13.2	69.8	801	1.46
Endosulfan (Endochem) 35 EC 0.05%	24.1	45.9	496	0.99
Trizophos (Hostathion) 40 EC 0.05%	24.5	44.0	530	1.04
Spinosad (Tracer) 45 SC 0.018%	22.1	49.5	619	0.89
Fipronil (Regent) 5 SC 0.02%	16.3	62.7	604	1.13
Neem seed extract 5%	26.2	40.0	546	1.08
B.t. 0.1 %	23.8	45.6	428	0.85
Control	43.7	00.0	160	0.34
SEm+	4.3	-	85	-
C.D (P=0.05)	12.97	-	259	-

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Efficacy of insecticides against thrips (*Retithrips syriacus* Mayet) infesting castor (*Ricinus communis* L.) in Gujarat

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Abstract

Thrips is an important sucking pest of castor in Saurashtra region of Gujarat. Eleven insecticides were tested to evaluate their efficacy against thrips of castor. The pooled data of three years revealed that although all the insecticides tested were significantly superior in reducing thrips population as compared to that in control, the most effective insecticides were acephate 75 SP 0.05% followed by polytrin 44 EC 0.044% (Profenophos 40% + cypermethrin 4%), dimethoate 30 EC 0.03%, profenophos 50 EC 0.1%, endosulfan 35 EC 0.07% and imidacloprid 17.8 SL 0.005%.

Keywords: Castor, thrips, efficacy, insecticides

Introduction

Castor, *Ricinus communis* L. is an important non-edible oilseed crop of India, grown widely in the states of Gujarat and Andhra Pradesh. Among the insect pests, thrips, *Retithrips syriacus* Mayet is an important sucking pest causing damage to leaves and inflorescences of castor crop. Owing to infestation of thrips, the leaf of the plant remains under developed with a curling shape. Damage in inflorescences has adverse effect on seed setting and ultimately it affects the yield. Khanpara and Patel (2002) have reported the avoidable loss in yield mainly due to sucking pests to be 14.96 % and 12.37 % in GCH-2 and GCH-4, respectively. Chemical insecticides are applied by the farmers for quick and effective control of the pest. The present investigation was aimed to study the effectiveness of newer insecticides against thrips under Saurashtra agro-climatic conditions.

Materials and methods

Field experiments were conducted in a randomized block design with 12 treatments and three replications at Main Oilseed Research Station Farm, Junagadh Agricultural University, Junagdh during rainy and winter seasons from 2004-05 to 2006-07. Castor (var. GCH-6) was sown on 20th July, 6th August and 2nd September in 2004-05, 2005-06 and 2006-07, respectively. Each plot (6.0 m x 4.5 m^2) had five rows consisting 50 plants at the distance of 90 cm x 60 cm. Twelve insecticides were applied as spray once at sufficient population of thrips (7 thrips/flag leaf/plant) found on the flag leaves. Observations on the number of thrips present on flag leaf of five randomly selected plants from each plot were recorded at 24 hrs before the spray and 48 hrs and 7 days after the spray. Data were subjected to ANOVA using square root transformation.

Results and discussion

The pooled data of three years on population of thrips at 48 hrs after spray of insecticides remained significantly low in all the treatments in comparison to control (Table 2). Significantly lowest population of thrips was recorded in the treatment profenophos 40% + cypermethrin 4% (Polytrin 44 EC) 0.044% and was found at par with treatments of dimethoate, acephate and profenophos at 48 hrs after spray. Endosulfan 0.07% and imidacloprid 0.005% were equally effective in population reduction of thrips and they were at par with profenophas 0.1% at 48 hrs after spray. The remaining treatments *were less effective.*

Similarly, at 7 days after spray population of thrips remained significantly low in all the treatments in comparison to control (Table 3). However, acephate was most effective followed by profenophos and dimethoate over other insecticides. Acephate has been reported as the most effective insecticide in controlling thrips on chilli (Kumar *et al.*, 2001) and also in grapevine (Reddy and Rao, 2002). Polytrin was reported effective against thrips (*Scirtothrips dorsalis* Hood) in cotton (Kazi *et al.*, 2004).

Thus, this study revealed that for the effective control of thrips infesting castor the most effective insecticide was acephate. The order of effectiveness of other chemicals in their descending order was polytrin, dimethoate, endosulfan and imidacloprid.

Table 1 Efficacy of insecticides against thrips at 24 hrs before spray

Treatment	No. of thrips/flag leaf/plant											
	Before spray				48 hrs after spray				7 days after spray			
	2004	2005	2006	Pooled	2004	2005	2006	Pooled	2004	2005	2006	Pooled
Dimethoate 30 EC 0.03%	3.1* (8.9)*	4.0 (16.0)	2.8 (7.4)	3.3 (10.6)	1.0 (0.5)	1.4 (1.6)	1.3 (1.2)	1.26 (1.1)	1.9 (3.1)	1.8 (2.8)	1.4 (1.5)	1.7 (2.4)
Endosulfan 35 EC 0.07%	2.9 (8.0)	4.1 (16.7)	2.8 (7.4)	3.3 (10.3)	1.3 (1.3)	1.8 (1.7)	1.5 (1.7)	1.5 (2.0)	2.3 (4.9)	2.5 (5.8)	1.5 (1.7)	2.1 (3.99)
Carbaryl 50 WP 0.15%	2.9 (7.9)	4.1 (16.3)	3.0 (8.6)	3.3 (10.6)	2.4 (5.3)	2.9 (8.2)	2.6 (6.5)	2.6 (6.6)	3.6 (12.9)	3.6 (12.8)	2.4 (5.4)	3.2 (10.1)
Acephate 75 SP 0.05%	2.8 (7.6)	4.1 (16.0)	3.1 (9.5)	3.3 (10.7)	1.0 (0.5)	1.5 (2.0)	1.3 (1.4)	1.3 (1.2)	1.1 (0.5)	1.5 (1.7)	1.1 (0.6)	1.1 (0.9)
Imidacloprid 17.8SL 0.005%	3.1 (9.2)	4.1 (16.4)	2.9 (8.2)	3.4 (11.1)	1.5 (1.8)	2.2 (4.6)	1.7 (2.5)	1.8 (2.8)	2.6 (6.3)	2.4 (5.4)	1.7 (2.6)	2.2 (4.6)
Carbosulfan 25 EC 0.03%	2.8 (7.4)	4.1 (15.8)	2.6 (6.4)	3.1 (9.4)	1.6 (2.1)	2.7 (7.2)	2.1 (3.9)	2.1 (4.2)	3.3 (10.5)	3.3 (10.8)	2.4 (5.3)	3.0 (8.6)
λ-cyhelothrin 5 EC 0.005%	2.9 (8.6)	4.1 (16.7)	3.1 (8.9)	3.3 (10.9)	1.6 (2.1)	2.3 (4.8)	1.7 (2.6)	1.9 (3.1)	2.7 (6.9)	2.7 (7.1)	2.2 (4.5)	2.5 (6.1)
Profenophos 50EC 0.1%	3.0 (8.9)	4.2 (17.2)	2.6 (6.5)	3.3 (10.5)	1.1 (0.6)	1.7 (2.6)	1.4 (1.6)	1.4 (1.5)	2.1 (4.2)	2.2 (4.4)	1.4 (1.6)	1.9 (3.3)
Profenophos 40% + Cypermethrin 4% 0.044%	3.0 (9.0)	4.1 (16.3)	2.9 (7.9)	3.3 (10.5)	0.9 (0.4)	1.2 (1.1)	1.1 (0.8)	1.1 (0.8)	1.8 (2.8)	1.8 (2.7)	1.3 (1.3)	1.6 (2.2)
Thiamethoxam 70WS 0.006%	2.7 (7.1)	4.1 (16.3)	2.7 (6.7)	3.2 (9.6)	2.7 (6.9)	3.6 (12.4)	2.6 (6.5)	2.9 (8.4)	4.1 (16.1)	3.7 (13.8)	2.4 (5.5)	3.4 (11.2)
Acetamiprid 20 SP 0.004%	3.1 (9.3)	4.2 (17.6)	2.9 (8.3)	3.4 (11.4)	1.8 (3.1)	2.7 (7.1)	2.5 (5.8)	2.4 (5.2)	2.8 (7.3)	2.8 (7.8)	2.3 (4.8)	2.6 (6.6)
Control	3.0 (8.7)	4.2 (17.2)	2.9 (7.9)	3.3 (10.9)	3.1 (8.8)	4.8 (22.8)	3.2 (10.5)	3.7 (13.4)	4.4 (19.3)	4.5 (20.3)	3.2 (10.1)	4.1 (16.3)
SEm±	0.18	0.25	0.17	0.11	0.11	0.16	0.10	0.14	0.19	0.18	0.10	0.14
CD (P=0.05)	NS	NS	NS	NS	0.33	0.48	0.28	0.41	0.56	0.53	0.28	0.42
Sem±				0.2				0.13				0.16
CD (P=0.05)				NS				0.36				0.46
CV (%)	10.5	10.4	10.2	10.5	11.6	11.6	8.60	10.9	12.1	11.2	8.4	11.2

* Square root (x+0.5) transformation value; ** Retransformed value

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Evaluation of insecticides against wireworm (*Gonocephalum* sp.) infesting castor (*Ricinus communis* L.) in Gujarat

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Abstract

Castor (*Ricinus communis* L) is damaged by many pests of which false wireworm *Gonocephalum* spp. is an important destructive pest in Saurashtra region of Gujarat causing severe damage at seedling stage. Eight insecticides were tested to evaluate their efficacy against this soil-inhabiting insect. The pooled data of two years on % dead plant by wireworm revealed that imidacloprid 70 WS @ 5 g/kg seed was the most effective insecticide which reduced the damage of seedlings significantly and gave the highest seed yield. Thiamethoxam 70 WS @ 3 g/kg seed, carbofuran 3G @ 33 kg/ha (furrow application) and phorate 10G @ 10 kg/ha (furrow application) were also effective against wire worms.

Keywords: Castor, wireworm, evaluation, insecticides

Introduction

There are many insect pests causing severe damage to inflorescences and leaves of castor crop. However, a new soil-inhabiting insect pest, false wireworm *Gonocephalum* spp has been observed since last few years in castor crop in Saurashtra region of Gujarat. This pest causes damage at seedling stage by chewing the young seedlings just below ground level. The population of the plants in the field reduces as the damaged seedlings do not survive after the injury of wireworm, which affect the yield. Hence, it is necessary to control this pest at the early stage itself. Therefore, the present investigation was thus undertaken to study the effectiveness of insecticides against wireworm *Gonocephalum* spp. under Saurashtra agro-climatic conditions.

Materials and methods

Field experiments were conducted in a randomized block design with nine treatments and three replications at Main Oilseed Research Station Farm, Junagadh Agricultural University, Junagadh during rainy-winter season from 2005-06 and 2006-07. Castor (var. GCH-6) was sown on 6th August and 2nd September in 2005-06 and 2006-07 respectively. Each plot (6 x 4.5 m^2) had five rows consisting 50 plants at the distance 90 cm x 60 cm.

Insecticidal dusts and granules were applied in furrow at the time of sowing whereas seed dressing insecticides were applied as seed treatment. Initial plant population was recorded in each plot after the germination of seed. Observations on the total number of plants died due to wireworm were recorded at weekly intervals till the crop reached one month stage. Seed yield was recorded at harvest.

Results and discussion

The pooled data of two years revealed that the % dead plant due to wireworm on castor cv. GCH-6 at one month after germination remained significantly low in all the treatments in comparison to that of control. The application of imidacloprid 70 WS proved as the most effective among the chemicals used by recording significantly the lowest % dead plant due to wireworm than rest of the treatments (Table 1).

Table 1 Effect of insecticides against wireworm in castor

Treatment	% dead plant (one month old crop)			Seed yield kg/ha		
	2005	2006	Pooled	2005	2006	Pooled
Thiamethoxam 70 WS 3 g/kg seed	2.51* (05.8)**	2.5 (05.7)	2.5 (05.7)	2471	2321	2396
Carbosulfan 27.18 DS 5 g/kg seed	3.2 (10.0)	3.3 (10.8)	3.3 (10.4)	2160	2082	2121
Imidacloprid 70 WS 5 g/kg seed	1.4 (01.4)	1.7 (02.5)	1.5 (01.9)	2560	2551	2556
Carbaryl 50 WP 5 g/kg seed	3.4 (10.8)	3.2 (09.9)	3.2 (10.3)	2157	2034	2095
Phorate 10 G @ 10 kg/ha (furrow)	2.8 (07.5)	2.9 (08.3)	2.9 (07.8)	2266	2208	2237
Carbofuran 3 G @ 33 kg/ha (furrow)	2.9 (08.2)	2.6 (06.6)	2.8 (07.3)	2432	2156	2294
Methyl parathion 1.5 % dust @ 50 kg/h (furrow)	3.5 (11.6)	3.2 (09.9)	3.3 (10.7)	2098	2028	2063
Quinalphos 1.5 % dust @ 67 kg/h (furrow)	3.2 (09.9)	3.3 (10.8)	3.2 (10.3)	2108	1983	2046
Control (Untreated)	4.1 (16.6)	4.0 (15.8)	4.1 (16.2)	1983	1829	1906
SEm±	0.2	0.1	0.1	73.2	72.1	51.4
CD (P=0.05)	0.6	0.4	0.3	219.4	216.1	148.0
SEm±			0.1			18.0
CD (P=0.05)			NS			52.0
CV (%)	11.5	8.1	9.9	5.6	5.9	5.7

* Square root (x+0.5) transformation value; ** Retransformed value

Thiamethoxam 70 WS followed by carbofuran 3G were the next best treatments. The other insecticides were less effective compared to above mentioned ones. The % dead plant was the highest in control (16.24 % dead plants). Earlier Trotus *et al.* (2000) reported that insecticides, such as imidacloprid and thiamethoxam as seed treatment gave efficient wireworm control with no toxic effects on maize and sunflower crops. The seed yield data of individual as well as pooled revealed that imidacroprid was significantly superior in reducing wireworm infestation by giving higher seed yield followed by thiamethoxam, carbofuran and phorate (Table 1). Therefore, seed treatment with imidacloprid 70 WS @ 5 g/kg seed or by thiamethoxam 70 WS @ 3 g/kg seed or carbofuran 3 G @ 33 kg/ha (furrow application) or phorate 10 G @ 10 kg/ha (furrow application) should be made.

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Survey of plant parasitic nematodes associated with castor (*Ricinus communis* L.) in and around Hyderabad

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Abstract

Random soil samples were collected from the rhizosphere of castor crop in Ranga Reddy, Mahabubnagar and Nalgonda districts of Andhra Pradesh. Reniform nematode (*Rotylenchulus reniformis*) was found major plant parasitic nematode with an absolute frequency of 35% and an average density of 1.5 nematodes/cc soil.

Keywords: Castor, *Rotylenchulus reniformis*

Introduction

Castor crop has been known to be attacked by many pests and diseases. Plant parasitic nematodes are one among them. Yield decline due to nematodes is elusive and often misleading because of lack of any visual symptoms. Nevertheless these subterranean serpents causes considerable yield reduction over a period of time as Jain *et al.* (2007) indicated that reniform nematode alone inflicts monetary loss of Rs. 180 million (13.93% avoidable yield loss) in castor. Surveying and sampling are the foremost steps for diagnosing nematode problems an identification of nematode hot spots for their management.

Materials and methods

A roving survey was carried out in the major castor growing belt of Andhra Pradesh with an objective to find out the major hot spots for nematode problem. A total of 20 random soil samples were collected from Ranga Reddy, Mahabubnagar and Nalgonda districts. Each soil sample consists of mixture of 10 sub-sample cores collected from various parts of farmer's field. These sub-sample cores were mixed and from that around 250 cc sample was taken for nematode extraction. Information regarding soil type, cropping pattern, cultivar used etc. were also collected. These samples were stored at 10°C and processed in a week. Two hundred cc of soil sample was taken for extraction and Cobb's sieving and decanting method (Cobb, 1918) was employed. The extracted nematodes were fixed in FA 4:1 solution. Plant parasitic nematodes were counted using De grisse counting dish under stereoscopic microscope. Frequency and density were calculated (Norton, 1978).

Results and discussions

Out of 20 soil samples processed only six were found positive for plant parasitic nematode. Reniform nematode (*Rotylenchulus reniformis*) was found major plant parasitic nematode of economic importance with an absolute frequency of 35% and absolute density of 1.5 soil inhabiting stages per cc soil. Other nematode genera *viz. Hoplolaimus* sp., *Helicotylenchus* sp., *Aphelenchoides* sp. do occur, but due to sporadic and less numericity they were not considered for analysis. Three reniform nematode hotspots were identified by calculating the nematode population exceeding one nematode per cc soil. They were Manchal and Japal mandals of Ranga Reddy district and Sankatonipalli village of Mahabubnagar district (Table 1). Similar observations have been recorded by John Sudheer *et al.* (2008) where Mahabubnagar district was listed as reniform nematode hotspot with relative frequency of 52.76% and relative density of 48.62%.

Gaur *et al.* (2005), observed reniform nematode as the predominant plant parasitic nematode in Andhra Pradesh with highest frequency of occurrence (52%) among different states of India. They also reported Hyderabad district with 20% of frequency of occurrence for this nematode.

Table 1 Surveying and identification of hot spots for reniform nematode associated with castor

District	Mandal	Village	Cultivar	Nematode population/200 cc soil
Ranga Reddy	Manchal	Manchal	Local	83.3
		Manchal	Local	0
		Manchal	Local	0
		Lingampally	DCH 519	50
		Manchal	48-1	2566
		Japal	DCH 177	0
		Japal	DCH 519	688
		Japal	Local	0
Nalgonda	Chityal	Gundranpally	48-1	0
		Aepor	DCH 519	0
		Aepor	DCH 519	0
		Aepor	DCH 177	40
Mahabubnagar	Amangal	Sankatonipalli	Local	0
			Local	0
			Local	0
			Local	2483
	Kathakota	Kanimetta	DCH 177	0
			48-1	0
			Local	100
			Local	0

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Identification of sources of resistance to major insect pests of castor, *Ricinus communis* L.

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Abstract

Castor germplasm was screened at Regional Agricultural Research Station, Palem during rainy season of 2009 against major insect pests. Already identified castor genotypes of promising, against leaf hoppers and thrips from various locations were also reevaluated under controlled conditions and high pest pressure by artificial release under netted conditions. The entry, RG-1280 with triple bloom was identified to be highly resistant to leaf hopper. The entry, RG-1919 with less number of thrips/top leaf proved to be resistant to thrips. A few genotypes resistant to leaf hopper and thrips with low pest infestation and low hopper burn were also identified. In the germplasm screening, several entries were found to be resistant to major insect pests like leaf hopper, semilooper, Spodoptera, capsule borer and thrips. These entries can be utilized successfully in breeding programmes for incorporating the resistance source.

Keywords: Castor, bloom, leaf hopper, resistance

Introduction

Castor (*Ricinus communis* L.) is one of the industrially important non-edible oilseed crops of the world. India is the major producer of castor with 64% share in the world followed by China (23%) and Brazil (7%). In India, Gujarat, Andhra Pradesh and Rajasthan are the major castor producing states. The productivity of castor in India during 2003-04 is 1292 kg/ha, which is more than the world average of 942 kg/ha. For the last 10 years, castor is being cultivated in 2.0-4.0 lakh ha in Andhra Pradesh especially in southern Telangana districts of Mahboobnagar, Nalgonda and Rangà Reddy. During 2008-09 castor crop was grown in 8.50 lakh ha with 11.23 lakh t production and productivity of 1321 kg/ha, but in Andhra Pradesh it is cultivating in an area of 1.59 lakh ha with the production of 0.81 lakh t but the productivity is only 511 kg/ha mainly due to a number of biotic stresses including insect pests (FAO, 2009). Castor crop suffers from defoliators like semilooper, tobacco caterpillar, hairy caterpillars *viz.*, bihar hairy caterpillar and Euproctis hairy caterpillar, leaf hoppers, thrips and capsule borer. Management of these insect pests involves frequent application of insecticides, while management of capsule borer often becomes difficult with insecticides as it is an internal feeder (Lakshminarayana and Raoof, 2005). The best management strategy for these major pests is the development of resistant castor cultivars. Hundreds of castor germplasm lines were available and were screened against leafhoppers and thrips at different locations in India and some accessions were reported to be promising. In the present investigation, 160 germplasm lines against different insect pests and few selected castor accessions reported to be promising to leafhopper and thrips were evaluated against these pests under controlled conditions and high pest infestations to identify the reliable source of resistance.

Materials and methods

Germplasm screening : Germplasm screening (160 entries + three local checks) was conducted in augmented block design, keeping the local check, after every 10 entries during the rainy season of 2009 at Regional Agricultural Research Station, Palem with plot size of 891 m^2. All the entries were sown on 15-7-2009.

Each entry was sown with 6m row length adopting 90 cm x 60 cm spacing. The genotypes had either red or green stem and with varied bloom characters. Observations on the incidence of leafhoppers, semilooper, tobacco caterpillar, hairy caterpillars, capsule borer and thrips were recorded starting from 45 days after sowing and at fortnightly interval on five plants in each entry. In each observation, population of leafhopper nymphs and adults were counted on 3 leaves (top, middle and bottom/plant). Similarly, the foliage drying due to hopper burn was recorded on 0-4 scale (0: No injury; 1: Hopper burn up to 10%; 2: Hopper burn 11 to 25%; 3: Hopper burn 26 to 50%; 4: Hopper burn above 50%) (Anonymous, 1998). The mean population of leafhopper and hopper burn for each entry was computed for each observation. For semilooper, *Spodoptera litura* and other hairy caterpillars, absolute larval population and the extent of damage was recorded based on visual observation. For capsule borer observations on total number of capsules and capsules damaged by the borer were recorded on primary and secondary spikes of each entry. Mean capsule borer damage both on primary and secondary spikes was computed. For thrips, number of thrips/top most leaf was recorded.

Confirmation of promising entries

Leafhopper: Confirmation of identified genotypes found promising against leafhoppers was conducted in randomized block design with six castor entries and four local checks and replicated thrice.

Thrips: The experiment was conducted in randomised block design with three selected castor genotypes and four local checks with three replications.

In the above experiment the castor genotypes were screened under heavy infestation of leaf hopper and thrips induced by artificial release of pest inoculum under netted conditions and observations were recorded similar to the above experiment.

Results and discussion

Screening of germplasm

Leafhopper: In the germplasm screening, the entries, RG-13, 58, 477, 725, 747, 768, 774, 808, 872, 908, 1200, 1302, 1303, 1345, 1554, 1579, 1611, 1696, 1707, 1709, 1724, 1759, 1880, 1904, 1908, 1980, 2014, 2018, 2712, 2725 and 2729 did not show any hopper burn and recorded relatively low hopper population (10-29.7 leaf hoppers/3 leaves/plant) and were considered to be highly resistant.

Foliage feeders: Semilooper: The entries RG-61, 220, 328, 467, 679, 696, 768, 813, 872, 898, 1435, 1709, 1834, 1864, 1971, 1978, 2046, 2429, 2712, 2729, 3007, 3120, 3195 and 3198 were found to be promising to semilooper population with less number of larvae (0.3 to 0.8) /plant. These entries can be utilized in breeding programme for developing the resistant cultivars. The entries RG-295, 426, 808, 1507, 1515 and 1611 with one larva/plant were also promising.

Spodoptera litura: The castor accessions *viz.*, RG-82, 98, 294, 408, 426, 477, 589, 790, 902, 1151, 1406, 1428, 1435, 1515, 1521, 1674, 1689, 1852, 2269, 2377, 2487, 2706, 2717, 2872, 3063, 3120, 3122, 3198 and 3217 were highly promising to tobacco caterpillar and recorded <1 larva/plant. The entries RG-220, 328, 969, 1280, 1354, 1880, 1980, 2266 and 3084 were also promising against *Spodoptera litura*, as the pest load was only one larva/plant (<0.8).

Hairy caterpillars: The entries RG-294, 673, 908, 1243, 1345, 1570, 1689, 2429 and 3217 were found promising to hairy caterpillars, as they recorded less number of hairy caterpillar larvae/plant (Table 1).

Shoot and capsule borer: Out of the 163 genotypes that were screened against shoot and capsule borer, 17 entries *viz.*, RG-72, 586, 768, 792, 808, 902, 905, 1435, 1654, 1674, 1880, 1904, 2544, 2706, 2712, 3164 and 3195 were found to be promising to the shoot and capsule borer as these entries have non-spiny capsules and recorded less than 10% damage by the borer. In castor varietal differences in susceptibility to capsule borer have been reported (Basu, 1948 and David *et al.*, 1964). In general, non-spiny varieties with loose spikes are tolerant to capsule borer rather than compact spikes (Anonymous, 2000).

Thrips: In the germplasm experiment, the entries, RG-673, 719, 845, 848, 860, 898, **2262, 2428, 2729 and the local check,** Kiran showed resistance reaction to thrips (3.8 to 5.8 thrips/ top leaf).

Confirmation of promising entries

In the confirmation of promising entries to leaf hopper infestation, wide variation was observed among the different castor accessions for leaf hopper population and hopper burn (Table 1). The accession RG-1280 did not show any hopper burn with low hopper population and were considered as highly resistant. Six entries *viz.*, RG-43, 2310, 2888, 1291, Haritha, Kranthi exhibited up to 25% foliage drying due to leaf hopper and were found to be resistant/moderately resistant. The susceptible entry, RG-1293 showed foliage drying of 25-50% with high leafhopper population. The genotypes with triple bloom were highly resistant to leafhopper and stem colour did not show any influence on the reaction of the test entries to leafhopper. Dorairaj *et al.* (1963) reported that castor varieties with double and triple bloom were usually resistant to leafhoppers. In the confirmation of promising entries to thrips infestation the entry RG-1919 recorded 10.7 number of thrips/ top leaf. So the entry, RG-1919 was found to be resistant to thrips followed by the local checks, Haritha, Kranthi, Kiran and CS-1 (15.8 to 21.2) (Table 2).

Table 1 Confirmation of reaction of promising entries to leafhoppers

Accession	Leafhoppers		Plant
	No./3leaves/plant	Hopper burn (0-4)	reaction
RG-43	42.9	0.8	R
RG-1280	22.2	0	HR
RG-2310	54.8	1.8	MR
RG-2888	39.2	1.1	R
RG-1291	36.8	1.0	R
RG-1293	60.5	3.2	S
Haritha	27.4	1.1	R
Kranthi	26.2	1.0	R
Kiran	52.4	1.9	MR
CS-1	68.6	1.8	MR

Table 2 Confirmation of reaction of promising entries to thrips

Accession	Number of thrips/ top leaf
RG-1919	10.7
RG-2064	25.2
RG-2128	22.8
Haritha	15.8
Kranthi	17.1
Kiran	21.2
CS-1	19.8

R = Resistant; MR = Moderately resistant; S = Susceptible

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Screening of varieties and hybrids of castor (*Ricinus communis* L.) for resistance against Reniform nematode (*Rotylenchulus reniformis* Linford and Oliveira, 1940)

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Abstract

Castor (*Ricinus communis* L.) is an important oilseed crop of industrial value. Reniform nematode, *Rotylenchulus reniformis* is an important biotic constraint of castor production in India. Host plant resistance offers cost-effective, eco-friendly and effective control of nematode damage. Among the castor varieties and hybrids screened, GCH 7 was found moderately resistant against reniform nematode infection.

Keywords: *Rotylenchulus reniformis*, host plant resistance, eggmass index, castor

Introduction

Castor (*Ricinus communis* L.) is one of the most important non-edible oilseed crops of the world, cultivated in many tropical and subtropical regions of the world (Govaerts *et al.*, 2000). India is the leading producer of castor with 59% of the world castor area and 64% of the total crop production. India produces 3.5 - 4.0 lakh t of castor oil annually and exports nearly 70% to the USA, Europe, Japan and other countries (Damodaram and Hegde, 2007). In India, yield loss estimates indicated that reniform nematode inflicts monetary loss of ₹180 million (13.93% avoidable yield loss) in castor crop (Jain *et al.*, 2007). The nematode also interacts with *Fusarium* wilt thereby aggravating wilt incidence.

Materials and methods

The 16 varieties and hybrids of the castor were obtained from Directorate of Oilseeds Research, Hyderabad as well as various AICRP castor centers are used in the present study. Earthen pots of 15 cm diameter were filled with sterilized sand + soil mixture (1:1) and sown with different cultivars of castor. Ten days after sowing, 500 reniform nematodes were injected in to the collar region of the plant and kept in completely randomized design for 30 days in glasshouse. Then the plants were uprooted and washed free of soil. The nematode eggmasses were counted under microscope. Scale of resistance was calculated based on eggmass index developed by AICRP (nematodes) where, no egg masses/plant - Highly resistant (HR), 1-10 egg masses/plant - resistant (R), 11-20 egg masses/plant - Moderately resistant (MR), 21-30 egg masses/plant - Susceptible (S) and more than 30 egg masses/plant - Highly susceptible (HS) (Gaur *et al.*, 2001).

Results and discussion

Among the 16 cultivars and hybrids screened, 13 have showed highly susceptible reaction with eggmass count ranging from 31 to 85 while, two of them showed susceptible reaction. Only castor hybrid GCH 7 showed moderately resistant reaction with an average eggmass count of 12.0 (Table 1). These result are in accordance with AICRP castor report (Anonymous, 2006) where the hybrid GCH 7 showed resistant to reniform nematode - wilt complex. In our results, GCH 5 and DCS 9 showed susceptible reaction which is not in accordance with the AICRP nematodes report where these were found moderately resistant (Gaur *et al.*, 2001).

Table 1 Screening of varieties and hybrids of castor for resistance against reniform nematode (*Rotylenchulus reniformis*)

Variety / hybrid	Average no. of eggmasses per root system	Reaction
Aruna	85.0	HS
Sowbhagya	25.7	S
48-1	51.0	HS
TMV 5	44.0	HS
TMV 6	32.0	HS
GC 2	49.3	HS
DCS 9	35.0	HS
Kranti	33.3	HS
Haritha	39.0	HS
GCH 4	46.0	HS
GCH 5	22.3	S
GCH 7	12.0	MR
DCH 177	53.7	HS
DCH 519	37.3	HS
RCH 1	38.3	HS
TMVCH 1	31.0	HS

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Sources of resistance in castor against capsule borer, *Conogethes (Dichocrocis) punctifaralis* Guen.

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Abstract

Capsule borer, *Conogathes (Dichocrocis) punctifaralis* Guen. (Pyralidae: Lepidoptera), is a devastating pest of castor crop in India. Chemical measures are not effective in managing the pest. Therefore, 55 castor germplasm accessions were screened under caged condition against capsule borer. Diverse reaction of castor germplasm accessions against capsule borer was observed. Five accessions *viz.*, RG-1934, 2546, 2770, 2786 and RG 2543 were found promising against capsule borer with 14 to 25% capsule damage as against 84% in DCS-9.

Keywords: *Capsule borer, castor, germplasm, resistance*

Introduction

Capsule borer, *Conogathes (Dichocrocis) punctifaralis* Guen. (Pyralidae: Lepidoptera), is the most serious pest of castor (*Ricinius communis* L.) in India. Its infestation starts from flowering stage onwards. The moth lays eggs on flower buds, developing capsules and to some extent on young shoots. The hatched larvae enter the capsule by boring hole and feed on developing and matured seeds. Under severe infestation, it attacks even shoots causing death of plants (David *et al.*, 1964). The pest is generally active throughout castor growing season and completes four to five overlapping generations. Yield loss to the tune of 53% in castor sole crop and 35 to 53% when castor was intercropped with green gram, sesame, moth bean and cowpea was reported (Patel and Patel, 2009). Chemical control of the pest is not effective as the larvae after hatching bore into capsules and pupate there. Breeding for capsule borer resistance is an effective means to manage the pest. To search for sources of resistance, castor germplasm was screened against capsule borer under caged conditions.

Materials and methods

Fifty five castor germplasm accessions collected from various parts of the country were screened during 2004-2009 under net-confined conditions along with checks, 48-1 and DCS-9 at the Directorate of Oilseeds Research, Hyderabad. One accession RG 2786 was screened under net in three contiguous years. The experiment was conducted in randomized block design with two replications. Each entry was grown in five rows with 90cm spacing between rows and 45 cm between plants in each replication. The experimental plots were covered with white nylon mosquito net at flowering initiation stage. To ensure adequate population of capsule borer on each plant for determining accurate reaction of entries, infested spikes with live capsule borers were kept inside nets at various places. These borers later on multiplied several folds under confined condition. Pest damage was recorded on primary and secondary spikes. Average damage in all plants of an accession was taken. Per cent capsule borer damage was derived from the ratio of the number of damaged capsules to the total capsules in a spike. The accessions exhibiting 1 to 10% capsule damage were graded as resistant, 10 to 25% as moderately resistant, 25 to 50% as susceptible and above 50% as highly susceptible.

Results and discussion

Net-confined condition ensured adequate population of capsule borer in experimental plots to carry out systematic screening. Diverse reaction of castor germplasm accessions against capsule borer was observed. Of the 55 accessions screened, 39 showed highly susceptible (52-97%) reaction, 11 exhibited susceptible (26-46%) reaction and five accessions recorded moderate resistant (14-25%) reaction (Table 1). Two of the moderately resistant accessions were originated geographically from Tamil Nadu while two were from Punjab and one was from Assam. It gives a clue that geographic origin had no role in pest resistance of an accession.

Table 1 Promising castor accessions against capsule borer

Accession	Capsule damage (%)	Geographical origin
RG 1934	25	Assam
RG 2546	21	Punjab
RG 2770	21	Tamil Nadu
RG 2543	18	Punjab
RG 2786	14	Tamil Nadu
48-1 (check)	18	
DCS-9 (check)	84	

Among the checks, 48-1 was found to be moderately resistant (18%) and DCS-9 was highly susceptible (84%) to capsule borer. The moderately resistant accession, RG 2786 exhibited consistent reaction against capsule borer in all three years being 8, 11 and 14%, respectively. Maturity duration of all accessions was within the range of checks (120-140 days). Compactness of spikes of RG 1934, RG 2770, RG 2786, 48-1 and DCS-9 was of loose type while that of RG 2546 and RG 2543 was of very loose. RG 2786 and 48-1 had non-spiny capsules whereas the remaining entries possessed spiny capsules. This gives an indication that spike and capsule traits do not play a definite role in capsule borer resistance.

The results were indicative of presence of diversity in castor germplasm for reaction against capsule borer and possibility of further identification of resistant and moderately resistant accessions when the entire germplasm collection is subjected to screening in future.

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Intercrop effect in castor *Botrytis* grey rot management - An assessment in the farmers fields of Ranga Reddy district of Andhra Pradesh

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Abstract

Castor is a predominantly grown rainfed crop in southern Telangana zone of Andhra Pradesh. In the recent past the disease caused by *Botrytis* grey rot is considered to be the major biotic constraint for castor production. In the absence of genetic resistance, it is imperative to manage the crop with integrated disease management technology. Field demonstrations were conducted in farmers fields of Ranga Reddy district to assess the strategies, such as redgram as intercrop in castor and adopting fungicidal sprays. The results clearly indicated that, there was a reduction in the disease in fungicide sprayed plots compared to the unsprayed (farmer's practice) plots. It was also evident from the study that the disease incidence was less in intercropped castor compared to the sole crop resulting in the productivity enhancement and also the net income of the dryland castor farmer.

Keywords: *Botrytis* grey rot, castor intercrop

Introduction

Castorbean or castor plant (*Ricinus communis* L.) is cultivated largely for its seed oil. Which is the World's most important industrial vegetable oils used as raw material in the manufacture of several products such as lubricants, varnishes, etc. The crop is predominantly grown in India in an area of 8.01 lakh ha and a production of 11.14 lakh million t. with a productivity of 1392 kg/ha (DOR, 2009). For the last several years, India has been the only country exporting castor oil and earning a foreign exchange of ₹ 800-1000 crores. In Andhra Pradesh, the crop is grown mostly as rainfed crop during the rainy season in an area of 3.0 lakh ha and the productivity is very low (513 kg/ha) due to several production constraints of which the grey rot disease caused by *Botrytis ricini* being major causing severe yield losses and needs a potential source of resistance and an effective management package. The disease some times may cause yield loss up to 60-90% under favourable weather conditions. Owing to the non-availability of resistant varieties for commercial cultivation, it is imperative to develop and disseminate the suitable management technology for effective control of this disease. Keeping this in view, intensive efforts were made and the management technology developed by Acharya N.G.Ranga Agricultural University was demonstrated in farmers fields of Ranga Reddy district of Andhra Pradesh.

Materials and methods

In Southern Telangana zone of AP, castor is a predominant rainfed oilseed crop during the rainy season. In this zone castor is cultivated along with pigeonpea (*Cajanus cajan* L.) as intercrop in about 17% of the castor cropped area. The castor-pigeonpea intercrop was encouraging in farmers fields with improved productivity and considerable increment in income to the farmers. In severe cases, the loss up to 80-90% was recorded due to the *Botrytis* disease (Moses and Reddy, 1989). During the last 12 years, epidemic of BGR was reported in four years and in the remaining years the losses range from 10-80%. As the cyclonic rain predispose the onset and spread of the disease, the disease incidence varies year to year (Janila *et al.*, 2006). White fungal mycelial growth will be seen on the spikes affected with the fungus due to continuous cyclonic rains and the capsules will get rot on the spike. It was observed that the staminate flowers were highly susceptible to the fungus and they become water soaked, wilted and densely covered with grey fungal growth. Infection appears as irregular spots on leaves, stems, branches and panicles (Godfrey, 1923).

The integrated disease management technology for castor *Botrytis* grey rot developed at the Regional Agricultural Research Station, Palem was demonstrated in farmers fields of Ranga Reddy district in three locations. The module with Kranti variety has treatments *viz.*, (1) summer deep ploughing; (2) intercropping with redgram (4:1 ratio); (3) carbendazim spray (1 g/l) as protective spray during flowering at least 6-8 hrs. before the onset of cyclonic rains and spray again after cessation of rains; (4) collection and destruction of grey rot affected spikes and (5) application of 10 kg N and 10 kg K_2O/ha after the cessation of rains by utilizing available soil moisture.

The field demonstrations were conducted in farmers fields of Ranga Reddy district in three mandals, the sowings were taken up in 4:1 ratio i.e., castor four rows and one row of redgram with recommended spacing of 90 cm x 60 cm. The farmers practice was kept as control i.e., unsprayed plot and in the demonstration plot the recommended spraying was taken up as per the University recommended module to evaluate for its sustenance. The incidence *Botrytis* grey rot and yields of castor and redgram was calculated.

Results and discussion

The incidence of *Botrytis* grey rot was severe during 2007-08 (36.8%) when compared to the years 2008-09 and 2009-10. Least incidence was noticed during 2008-09 due to low rainfall and dry spells. This might have hindered the disease development. The castor sole crop had higher disease incidence during 2007-08 (36.8%) followed by 2009-10 (12.2%) while it was less during 2008-09 (4.8%) in the unsprayed plot. Two sprays of carbendazim reduced the disease considerably during all the years in castor sole crop i.e., 30% during 2009-10 and 60% during 2007-08. The castor - redgram intercrop recorded less disease incidence when compared to sole crop in unsprayed treatment during all the years. Maximum incidence of grey rot was recorded during 2007-08 in unsprayed plot (20.9) while it is 36.8% in sole castor crop, a reduction of 43.2% in grey rot incidence. Least incidence of grey rot was observed in sprayed treatment with castor redgram intercrop (1.7) during 2008-09. Carbendazim spray reduced the disease incidence to an extent of 67.9% during 2007-08 (Table-1). The incidence of grey rot was controlled effectively with redgram, castor intercrop and spraying of carbendazim twice as recommended.

The yield obtained in castor and castor redgram intercrop were presented in table 2. The yield of castor were less during 2008-09 when compared to the other two years. In castor sole crop with out any management for *Botrytis* grey rot the highest yield was recorded during 2009-2010 (1583 kg/ha) followed by 2007-08 (909 kg/ha). The year 2009-2010 is a favourable year for castor where in the grey rot incidence was less (Table 2) and the yields were also more. The spray of carbendazim has not only reduced the incidence of grey rot but also increased the yield in all the years in castor sole crop. Highest yield of 1810 kg/ha was recorded during 2009-2010 with spray of carbendazim while it is 1583 kg/ha in unsprayed castor sole crop i.e., 14.3% increase. During all the years the spray of carbendazim has reduced the disease incidence and there by increased the yields in castor sole crop plots. Low yields were recorded in castor redgram intercrop when compared to castor sole crop. The redgram yields obtained in castor redgram intercrop has given an advantage there by the castor equivalent yields were more in castor redgram intercrop treatments. During 2009-2010, the sprayed plot of castor redgram intercrop has given highest yield (1892 kg/ha) when compared unsprayed castor redgram intercrop (1737 kg/ha) and also castor sole crop sprayed plot (1810 kg/ha). The disease incidence was also less in castor redgram intercrop sprayed plot when compared to other two treatments.

The economics were also calculated and were presented in table 3. The highest returns were obtained when castor was sown along with redgram as intercrop coupled with disease management for the grey rot. The castor redgram intercrop and the castor sole crop with management of grey rot were at par in yields and cost benefit ratio. So from the above studies it is clear that the castor redgram intercrop not only reduced the grey disease but also gave an additional red gram yield which is beneficial when equivalent yields of castor were computed. The management strategy against *Botrytis* disease using carbendazim spray was found to be very effective and the castor redgram intercrop was highly beneficial to the farmers when compared to all the other treatments.

The study proved clearly that the practice of planting of two crops alternately reduced the disease incidence may be by creating a physical barrier for the movement of disease inoculum. However, the selection of crops to be used as for intercropping is of prime importance. The present study showed significant results for recommending castor crop as intercrop with redgram in order to reduce the disease incidence and enhance the productivity of castor.

Table 1 Intercropping effect on the incidence of *Botrytis* grey rot in castor

Year	Castor sole crop			Cast-r redgram intercrop			
	Botrytis grey rot incidence (%)		% reduction	Un- sprayed	Sprayed	% reduction	% reduction of disease in unsprayed plot due to castor-redgram intercrop
	Unsprayed	Sprayed					
2007-08	36.8	14.7	60.0	20.9	6.7	67.9	43.2
2008-09	4.8	2.2	54.1	3.7	1.7	54.0	22.9
2009-10	12.2	8.5	30.3	8.1	4.9	39.5	33.6

Table 2 Yield of castor and castor-redgram intercrop

Year	Castor sole crop		Cast-r redgram intercrop					
	Yield kg/ha		Yield kg/ha					
			Unsprayed			Sprayed		
	Unsprayed	Sprayed	Castor	Redgram	Castor equivalent yield	Castor	Redgram	Castor equivalent yield
2007-08	909	1161	740	317	1125	1037	303	1404
2008-09	525	564	405	273	737	527	272	857
2009-10	1583	1810	1242	408	1737	1342	453	1892

Castor sale price - Rs. 2800/q; Redgram sale price - Rs. 3400/q; Redgram prices in 2009-10 (Rs.4500-5000)

Table 3 Economics of castor and castor redgram intercrop

Parameter	Castor sole crop		Castor redgram intercrop	
	Unsprayed	Sprayed	Unsprayed	Sprayed
Average yield (kg/ha)	1005	1178	1200	1384
Gross returns* (Rs.2800/ quintal)	28140	32984	33600	38752
Cost of cultivation (Rs.)	17381	18031	17206	17806
Net income (Rs.)	10759	14953	16394	20946
Benefit cost ratio	1.62	1.83	1.95	2.18

Prices: Mean of 3 years

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Seed quality attributes of castor genotypes in Andhra Pradesh

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Abstract

One hundred and twenty five castor seed samples were assessed for seed health, germination and seed vigour. In all the seed samples, seed germination ranged from 80-99% which is above minimum seed certification standard of >75%. Seed vigour ranged between 486-1096. Irrespective of places of collection of seed samples, seed borne fungi *viz., Fusarium oxysporum* (0.5-2.2%), *Macrophomina phaseolina* (0.5-1.0%), *Alternaria ricini* (0.5-3.5%), *Cladosporium herbarum* (0.3-3.3%), *Curvularia lunata* (0-3.5%), *Aspergillus flavus* (0.5-7.2%), *Aspergillus niger* (2.5-10.9%) were observed in the seed samples tested. Highest occurrence of seed borne fungi was observed in castor variety 48-1. Decreased germination and seedling vigour was observed in certain genotypes with increase in total number of fungal colonies. Heavily infected seeds did not germinate. Maximum occurrence of storage fungi like *A. flavus* and *A. niger* were observed in all the seed samples tested as compared to other field fungi. Seed rot and seedling blight was also high in variety 48-1 (22%) followed by hybrids and other castor varieties. Seed rot was not observed in castor varieties, Haritha and Kranthi and hybrid, PCH-111. Complete reduction in occurrence of seed borne fungi, seed and seedling blight was observed in castor seeds treated with carbendazim (0.1%) with improvement in seed quality attributes *viz.*, germination (84-99%) and seed vigour (824-1120) in the castor varieties.

Keywords: Castor, seed mycoflora, seed quality, seed treatment, carbendazim

Introduction

Castor *(Ricinus communis* L.) is an important industrial oilseed crop containing 50-55% oil in seed. The value of castor crop lies in its oil with myriad industrial applications and the demand is directly related to industrial growth. India is one of the primary centres of origin of castor and dominates world castor production accounting for 53% area and 70% of production. Andhra Pradesh stands second in area (2.62 lakh ha) and production (0.71 lakh t) and its average yield being lowest at 273 kg/ha primarily due to biotic and abiotic stresses. In the field, castor is attacked by a number of pathogens some of which are seed borne *viz., Fusarium oxysporum* f.sp. *ricini, Altemaria ricini* and pod and seed rot incited by *Cladosporium herbarum.* Infections by seed borne fungi results in seed discolouration, loss in seed viability and seedling mortality under field conditions ultimately which causes total yield losses. The present study report **fungal mycoflora associated with castor** cultivars and effect of carbandazim to seed treatment.

Materials and methods

Seed samples of castor varieties (Kiran, Haritha, Kranthi, DCS-9 and 48-1) and hybrids (DCH 519, DCH-177, PCH-111 and PCH-222) were obtained from research stations of ANGRAU and farmers from different agro-climatic zones of Andhra Pradesh. The occurrence of seed borne fungi (total fungal colonies), seed rot and seedling mortality were evaluated by blotter method. Germination percentage and seed vigour was tested by paper towel method during 2009-10. Four replications of 100 seeds from each seed sample were randomly counted and subjected to germination test by paper towel method (ISTA, 1996). Observations on seed germination, root length and shoot length were recorded after 10 days.

The seedling vigour index was determined as per Abdul Baki and Anderson (1973). For enumeration of before fungal colonies, blotter discs of 90 mm diameter were dipped in beaker containign sterile distill water with the help of forceps and ten seeds were placed at the bottom of each petri plate labelled and incubated at 28±2°C under alternating cycles of 12 h light and 12 h darkness for a period of seven days in BOD incubator. The plates were examined under stereo binocular microscope on 7th day and percentage total number of fungal colonies/400 seeds was calculated. Seed rot and seedling blight were also recorded.

Results and discussion

In all the castor seed samples, seed germination ranged from 80-99% which is above minimum seed certification standard of >75%. Seed vigour ranged between 486-1096. Castor varieties recorded significantly higher germination (88-99%) and seed vigour of 785-1096 except the variety, 48-1 which recorded 84% seed germination and seed vigour of 486. The germination percentage in hybrid seeds ranged between 80-87% while seed vigour varied from 650-1015 (Table 1). Irrespective of castor genotypes, occurrence of seed borne fungi, *Macrophomina phaseolina, Fusarium oxysporum, Alternaria alternata, Curvularia lunata, Aspergillus flavus, Aspergillus niger* and *Cladosporium herbarum* were observed among the castor genotypes. Occurrence of seed borne fungi was high in var. 48-1 (19.8%) followed by castor hybrids (15.2-17%). In the remaining 4 castor varieties occurrence of seed borne fungi varied from 10.5-12.2%. Storage fungi like *A. flavus* (0.5-7.2%), *A. niger* (2.5-10.9%) were observed more in castor varieties and hybrids. However, least occurrence of field fungi such as *Fusarium* (0.5-2.2%), *Macrophomina* (0.5-1.0%) and *Alternaria* sp. (0.5-2.5%) was noticed in all the castor seed samples. The occurrence of pod and seed rot fungi *Cladosporium* was between 0.3 to 3%. The differences in occurrence of seed mycoflora in different castor seed samples collected may be attributed to the moisture content of the seed and storage conditions (temperature, humidity and light) adopted by the farmers and at the research stations. With the increase in fungal colonies, decreased seedling vigour was observed in castor varieties DCS-9, 48-1 and castor hybrids DCH-519 and PCH-111. Seed rot and seedling blight was also high in Jwala (22%) as compared to hybrids (4-13%) and other castor varieties (1-7%). Seed rot varied from 2 to 5% in the castor seed samples. Seed rot was not observed in castor varieties, Haritha and Kranthi and hybrid PCH-111. The difference found in total seed rot and seedling decay might be attributed to the genetic make up of genotypes. These results are in conformity with Naik (1994) and Nagaraja *et al.* (2009) who reported that seed borne fungi reduced germination and seedling vigour. Most of the fungal species detected in this work have been reported earlier (Jain and Patel, 1969; Kanwar and Khanna, 1979) as pathogens on castor and affected the germinability.

Complete reduction of occurrence of seed borne fungi, seed and seedling rot was observed in castor seeds treated with carbendazim (0.1%) and enhanced seed quality attributes *viz.*, germination (84-99%) and seed vigour (824-1120) in castor varieties. While seed germination (83.5-88%) and seed vigour (750-1050) was noticed in hybrid seed samples tested. Seed treatment with carbendazim eliminated the seed borne infection of wilt pathogen in castor seed samples (Srinivasulu *et al.*, 1994). Irrespective of castor genotypes, seeds treated with carbendazim @ 0.1% were free from seed mycoflora with an improvement in seed germination and seed vigour was observed.

Table 1 Effect of seed borne fungi on seed quality parameters of castor genotypes under laboratory conditions during 2009-2010

Genotype	Germination (%)	Vigour index*	Seed rot (%)*	Seedling blight (%)*	Seed rot and seedling decay (%)	Total fungal colonies (%)	Seed treatment with carbendazim	
							Mean germination (%)	Vigour index
Varieties								
Kiran	88.0 (69.8)	1096	2.0 (7.8)	5.0 (12.8)	7.0	11.8 (20.1)	92.0 (73.6)	1120
Haritha	98.0 (82.0)	1089	0.0 (0.0)	1.0 (4.9)	1.0	10.5 (18.9)	99.0 (85.0)	1090
Kranthi	99.0 (86.0)	1080	0.0 (0.0)	2.0 (7.9)	2.0	10.9 (19.2)	99.0 (85.)	1092
DCS-9	90.0 (71.6)	785	4.0 (11.3)	2.0 (7.9)	6.0	12.2 (20.4)	92.0 (73.9)	824
48-1	80.0 (63.2)	486	10.0 (10.3)	12.0 (20.2)	22.0	19.8 (26.4)	84.0 (66.4)	520
Hybrids								
DCH-519	86.5 (68.4)	1015	3.0 (9.9)	9.0 (17.4)	12.0	15.7 (23.3)	88.0 (70.2)	1050
DCH-177	84.0 (66.4)	740	3.0 (9.5)	4.0 (11.5)	7.0	16.0 (23.6)	86.0 (68.2)	850
PCH-111	84.0 (66.7)	907	0.0 (0.0)	4.0 (11.3)	4.0	15.2 (22.9)	88.0 (70.0)	1020
PCH-222	80.0 (63.6)	650	5.0 (12.8)	8.0 (16.4)	13.0	17.0 (24.3)	83.5 (66.2)	750
CD (P=0.05)	4.4	32.6	2.6	2.6	-	1.9	5.1	73.0

* Average of four replications

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Evaluation of IPM modules in the farmers' participatory castor seed production involving tribal farmers in the Mahaboobnagar district of Andhra Pradesh

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Abstract

Effect of pest management options on the severity diseases and incidence of insect pests their natural enemies, yield and economics was studied in the farmers' participatory castor seed production by tribal farmers of Narlakunta Thand (Tribal village) in Mahaboobnagar District of Andhra Pradesh during 2000-01 and 2001-02. One each biointensive IPM (BIPM) and chemical insecticide intensive (CIPM) modules were compared with pesticides alone and farmers practice. BIPM module with regular crop rotation of castor with sorghum, summer ploughing, seed treatment with carbendazim @ 2 g/kg seed against seedling blight, Carbendazim (0.05%) prophylactic spray against botrytis, use of wilt resistant variety Jyoti, hand picking and destruction of egg masses and early stage larvae of tobacco caterpillar and hairy caterpillars, use of NSKE (5%) against castor semilooper, tobacco caterpillar and castor capsule borer, use of bird perches (15/ha) to attract insectivorous birds was effective in keeping pest population below economic threshold level and it was relatively safer to natural enemies compared to CIPM module, pesticides alone and farmers practice. CIPM module involving chemical insecticides, fenvalerate (0.01%) against castor semilooper, chlorpyriphos (0.05%) against tobacco caterpillar and monocrotophos (0.05%) against castor capsule borer in addition to above pest management options was effective in reducing pest load and relatively safer to natural enemies compared to pesticides alone and farmers' practice. BIPM, CIPM modules, pesticides alone and farmers practice recorded mean seed yield of 611.8, 614.4, 538.2 and 431.6 kg/ha, respectively. BIPM module recorded highest C:B ratio (1:4.40) followed by CIPM module (1:4.25), pesticide alone (1:3.34) and farmers' practice (1:1.92). In the farmers' participatory castor seed production BIPM and CIPM modules were found effective for management of pests under normal and outbreak conditions, respectively.

Keywords: Castor, insect pests, diseases, natural enemies, yield, economics

Introduction

Castor (*Ricinus communis* L.) is one of the non-edible and industrially important crops cultivated in different parts of the world. In India maximum castor is produced in Gujarat followed by Andhra Pradesh. In Andhra Pradesh castor is predominantly grown as a sole crop in marginal and sub marginal soils under rainfed agro-ecosystem of Ranga Reddy, Nalgonda and Mahaboobnagar districts.

Insect pests and diseases are the major biological constraints in the castor seed production. Among them, insect pests like red hairy caterpillars (*Amsacta albistriga* Walker); castor semilooper (*Achaea janata* Linn); castor shoot and capsule borer, (*Conogathus punctiferalis* (*Dichocrosis punctiferalis* (Guenee)); tobacco caterpillar (*Spodoptera litura* Fab.), leafhopper (*Empoasca flavescense* Fabricius) and diseases like seedling blight (*Phytophthora parasitica*); wilt (*Fusarium oxysporum* f.sp. *ricin*) and grey rot (*Botrytis ricini* Godfrey) are of greater economic importance. In castor ecosystem egg and larval parasitoids, insect predators and insectivorous birds exert greater biological resistance in the succession of insect pests of castor.

The author was one of the members of task force team (TFT) of farmers' participatory castor seed production programme surveyed farmers for their knowledge on insect pest and disease management in the traditional castor growing villages and it was felt essential to develop and evaluate biointensive IPM (BIPM) and chemical insecticide intensive (CIPM) modules for management of pests under normal and outbreak conditions, respectively in the castor seed production programme. Thus investigations were initiated involving tribal farmers on development and evaluation of BIPM and CIPM modules with an aim to manage pests under normal and outbreak conditions, respectively in the farmers' participatory castor seed production.

Materials and methods

Survey was conducted during May 2000 among146 farmers in the traditional castor growing villages like Karkalapahad, Narlakunta Thanda, Eluguralla Thanda and Gaddameedi Thanda (Tribal village) of Amangal Mandal under Mahaboobnagar district of Andhra Pradesh for farmers level of knowledge on insect pest and disease management in castor seed production. After survey five tribal farmers with minimum two hectare land holdings were selected from Narlakunta Thanda for imposing pest management options in castor seed production at different phonological stages of the crop (Table 1).

Since Narlakunta Thanda was one of the seed villages of DOR castor seed production programme, experiments were conducted during 2000-01 and 2001-02 in farmers fields by involving farmers. Farmers were trained under IPM field school on BIPM and CIPM components (details of various treatments given in footnote Table 1). During both the years observations on population of insect pests and their natural enemies, disease incidence and yield was recorded. Experiment was conducted in 20 acre area using minimum plot of one acre castor field per module with buffer castor crop between modules in castor fields of five farmers. Castor crop was grown by following recommended agronomic practices except plant protection.

Based on economic threshold level (ETL) for castor semilooper (4-5 larvae/plant), tobacco caterpillar (10-15% defoliation), capsule borer (10% capsule damage), wilt (15-20%) and *Botrytis* (10%) various BIPM and CIPM components under each module and pesticides alone were imposed and compared with farmers' practice (FP) by regularly recording insect pests, diseases and natural enemies apart from crop protection practices followed by farmers from seedling stage till harvest. The experiments were laid out in randomized block design. Apart from recording pretreatment and post treatment populations of castor semilooper, tobacco caterpillar, hairy caterpillars, castor shoot and capsule borer, natural enemies of these pests per plant were also recorded on five plants in 5 quadrates of 25^2 m. in one acre area under each module. Percent incidence of diseases like seedling blight, wilt and *Botrytis* were also recorded. During seedling stage weeds were managed by inter culturing in both the directions followed by removal of left over weeds near plants manually. Yield was recorded in the BIPM, CIPM modules, pesticide treatment alone and farmers practice fields of one acre area and worked out yield/ha. Economics of BIPM, CIPM , pesticide alone and farmers practice was worked out by considering expenditure, castor seed yield/ha and market price.

Results and discussion

All the components under different BIPM and CIPM modules and pesticides alone were imposed at different phenological stage of the crop based on ETL of insect pests and diseases. The results presented are based on the mean values of 2000-01 and 2001-02 years across the five farmers.

Insect pest population: Major defoliators like castor semilooper and tobacco caterpillar population was above ETL in both the years. Tobacco caterpillar population was kept below ETL in BIPM and CIPM modules by handpicking of egg masses and early stage larvae by walking in between two rows of castor twice in a week and also by predatory birds like common mynah and black drongo. Before imposing treatments there was no significant difference in the castor semilooper population in both the years. There was slow reduction in semilooper population at 1 day after spraying (DAS) in BIPM but the population was gradually decreased at 3 DAS and 7 DAS due to effect of NSKE and higher activity of larval parasitoid, *M. maculipennis* and predatory birds like common mynah, black drongo, green bee eater and crow.

In CIPM module, Pesticide alone there was drastic reduction in semilooper population at 1^{st} and 3^{rd} day after spraying insecticides the population was gradually raised at seven DAS due to elimination of larval parasitoid, *M. maculipennis* (Fig. 1). Similar observations were recorded by Basappa and Lingappa (2004). In farmers practice there was marginal population reduction because of spraying mixture of diamethoate + quqinalphos + carbendazim by one farmer and monocrotophos + carbendazim by another farmer which might have affected natural enemy activity. Three farmers did not follow any pest management options against pests and diseases which reduced yield drastically. *S. litura* population was kept below ETL in the pesticides alone treatment by spraying chlorpyriphos (0.05%) with the initiation of pest population. In farmers' practice *S. litura* population was above ETL and caused damage to spikes apart from leaf due to lack of timely spraying of effective insecticide. Compared to BIPM the incidence of capsule borer was above ETL (>10%) in CIPM, pesticides alone and farmers' practice due to use of insecticides which might have eliminated natural enemies of capsule borer. Among sucking insect pests moderate incidence of leaf hopper was noticed at the end of the season in both the years which did not affect the crop. Sporadic incidence of hairy caterpillars was noticed at the end of the season. In both the years, red hairy caterpillar did not emerge due to delay in monsoon hence there was no incidence in the experimental area.

Disease incidence: Due to erratic rainfall various levels of incidence of seedling blight (5-11%), *Fusarium* wilt (10-50%) and *Botrytis* (25-30%) were recorded in the traditional castor growing areas in both the years. The average incidence of seedling blight was negligible in BIPM, CIPM and pesticide treatments (1.2 to 1.6%) due to seed treatment with carbendazim @ 2 g/kg seed compared to 10.8% in farmers' practice. Since wilt resistant castor variety Jyoti was used in BIPM, CIPM modules, pesticides alone and farmers' practice hence there was no incidence of wilt disease. Similar results were recorded by Pushpavathi *et al.* (1998) while studying the resistance of cultivars for wilt. Incidence of *Botrytis* disease was low (12.5 to 14.2%) in BIPM, CIPM modules and pesticides alone compared to 28.2% in farmers' practice (Fig. 2). During 2000-01 one round of prophylactic spray of carbendazim (1 g/l) was given. In 2001-02, due to high incidence of *Botrytis* disease two prophylactic sprays of carbendazim (1 g/l) were given in addition to removal of affected spikes in BIPM and CIPM modules. Two farmers applied carbendazim along with insecticides at vegetative stage before occurrence of the disease and three farmers did not use any management options under farmers' practice which did not reduce *Botrytis* incidences.

Effect of BIPM, CIPM, pesticides alone and farmers' practice on natural enemies: The activity of promising natural enemies of castor semilooper like egg parasitoid, *T. chilonis* and larval parasitoid *M. maculipennis* was not much affected in BIPM module with NSKE along with other IPM components whereas in CIPM module there was moderate reduction in the activity of above parasitoids compared to minimum activity in the pesticides treated castor crop. Fenvalerate used in CIPM is relatively less harmful to resting stages of both the parasitoids than other insecticides (Basappa and Lingappa, 2002a). In the farmers' practice also natural enemy activity was reduced due to toxic effects of insecticides (Fig. 3 and 4). The results are in accordance with the findings of Basappa and Lingappa (2002b), who have reported that NSKE is harmless to natural enemies due to its weak contact on insects. Decrease in the parasitisation of *T. chilonis* and *M. maculipennis* in pesticides treatment and farmers' practice was attributed to the toxicity of synthetic insecticides to parasitoids as it was reported by Basappa and Lingappa (2002a).

Table 1 Yield and economics of BIPM, CIPM, pesticides alone and farmers' practice in castor seed production

Treatment	Yield (kg/ha)	C:B Ratio
BIPM Module	611.8	1:4.40
CIPM Module	614.4	1:4.25
Pesticides alone	538.2	1:3.34
Farmers' practice	431.6	1:1.92
CV	13.78	-
CD (P=0.05%)	28.58	

BIPM Module: *i)Crop rotation of castor with sorghum ii) Summer ploughing iii) seed treatment with carbendazim @2g/kg seed* iv) carbendazim (0.05%) prophylactic spray, v) wilt resistant variety Jyoti vi) hand picking and destruction of egg masses and early stage larvae of tobacco caterpillar and hairy caterpillars as well as *Botrytis* affected spikes vii) NSKE (5%) viii)perches(15/ha) to attract insectivorous birds.

CIPM Module: Component i, ii, iii, iv, v, vi, viii from BIPM module, fenvalerate (0.01%) against castor semilooper, chlorpyriphos (0.05%) against tobacco caterpillar and monocrotophos (0.05%) against castor capsule borer.

Pesticides: *Seed treatment with carbendazim @ 2 g/kg seed against seedling blight, carbendazim (1 g/l) prophylactic spray against* Botrytis, use of wilt resistant variety Jyoti, endosulfan (0.07%) against castor semilooper, chlorpyriphos (0.05%) against tobacco caterpillar and monocrotophos (0.05%) against castor capsule borer.

Farmers'practice: Use of wilt resistant variety Jyoti by all the five farmers, one farmer sprayed mixture of diamethoate + quqinalphos + carbendazim and another monocrotophos + carbendazim . Three farmers did not follow any pest management measures.

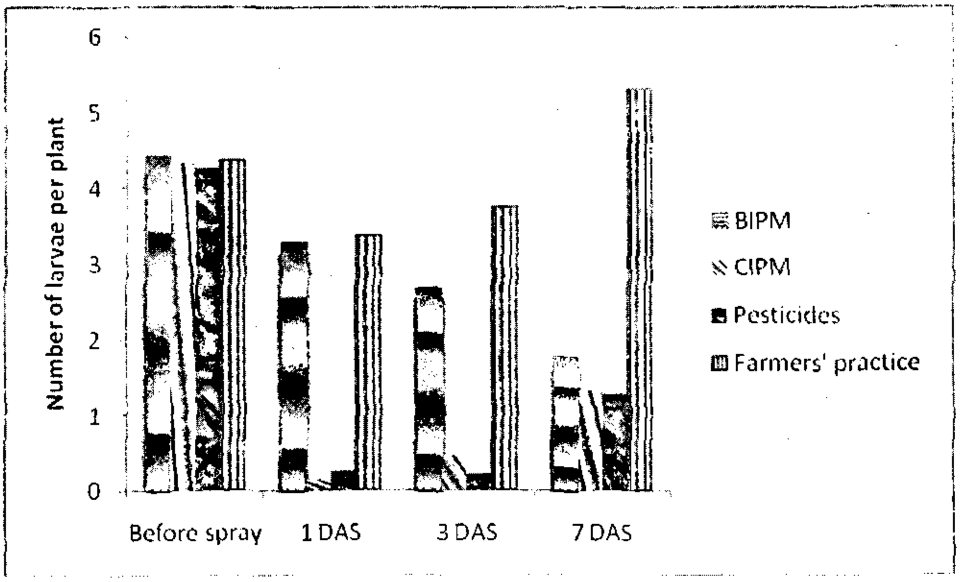

Fig. 1. Effect of BIPM, CIPM, pesticides alone and farmers' practice on castor semilooper in castor seed production

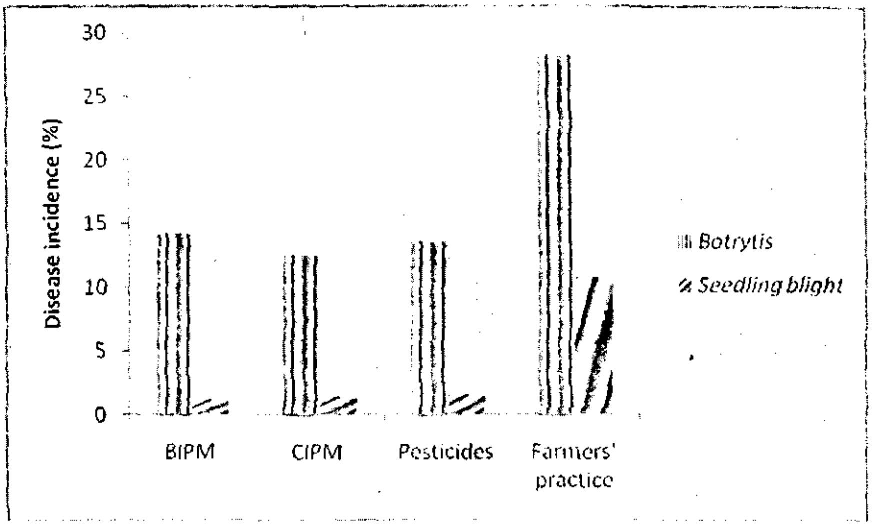

Fig. 2. Effect of BIPM, CIPM, pesticides alone and farmers' practice on diseases in castor seed production

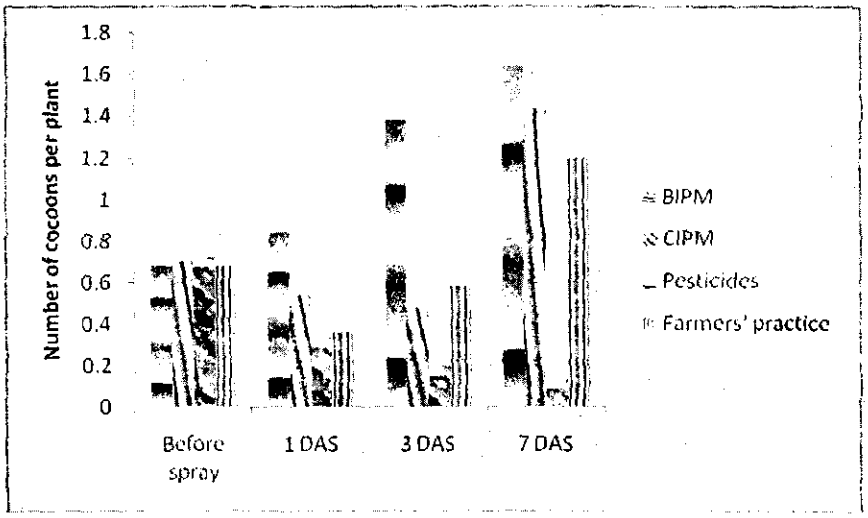

Fig. 3. Effect of BIPM, CIPM, pesticides alone and farmers' practice on *Microplitis* sp. larval parasitoid cocoon formation in castor seed production

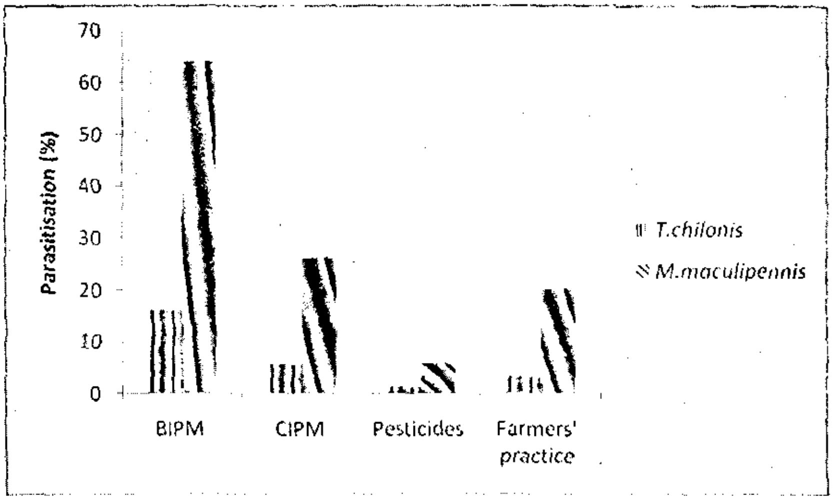

Fig. 4. Effect of BIPM, CIPM, pesticides alone and farmers' practice on egg parasitoid, *T. chilonis* and larval parasitoid *Microplitis* sp. parasitisation in castor seed production

Yield and economics: The mean seed yield of both the years across the five farmers in BIPM, CIPM modules, pesticides alone and farmers practice was 611.8, 614.4, 538.2 and 431.6 kg/ha, respectively. Cost : benefit ratio was highest in BIPM module (1:4.40) followed by 1: 4.25, 1: 3.34 and 1: 1.92 in CIPM module, pesticide alone and farmers' practice, respectively (Table.1). Castor seed yield was low in the farmers practice due to lack of timely pest management.

Both BIPM and CIPM modules are essential for different situations (Basappa, 2007). BIPM module is useful in keeping pest population below ETL and was also relatively safe to natural enemies in the castor seed production. Though CIPM module with insecticides reduced the activity of natural enemies to some extent but it is essential for drastic reduction of defoliators like castor semilooper and tobacco caterpillar when there is outbreak in the castor seed production. Apart from maintaining ecological balance BIPM and CIPM modules are economically viable and socially acceptable by tribal farmers for the effective management of insect pests and diseases in the farmers' participatory castor seed production.

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Effectiveness of DOR Bt-5 - A local isolate of *Bacillus thuringiensis* var. *kurstaki* against castor semilooper, *Achaea janata* Linn

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Abstract

A low-cost formulation of a local isolate of *Bacillus thuringiensis* var. *kurstaki* DOR Bt-5 multiplied through solid state fermentation was tested in the laboratory and field against larvae of castor semilooper *Achaea janata* Linn. The LC_{50} and potency of the formulation were found to be 39.63 mg/100 ml and 10,896 IU/mg, respectively. The formulation gave effective kill of the pest at the dose of 1.0 g/l and was on par with the commercial *Bt* formulation Delfin and the insecticidal check monocrotophos.

Keywords: *Bacillus thuringiensis*, castor semilooper

Introduction

Castor is an industrially important oilseed crop whose cultivation is constrained by vulnerability of the crop to several insect pests of which castor semilooper, *Achaea janata* is economically important. Incidence of the pest on castor crop generally occurs from 25 to 60 days after germination. Castor semilooper is a voracious feeder causing extensive defoliation (Chellaiah and Gopalan, 1967), also feeds on tender shoots and developing capsules leading to considerable reduction in yields (Parthasarathy and Rao, 1989). The pest is attacked by several natural enemies that include the egg parasitoid *Trichogramma chilonis* and three larval parasitoids *Microplitis maculipennis, Euplectrus maternae* and *Rhogas* spp. (Vimala Devi *et al.*, 2001). The insecticides fenvalerate, endosulfan, phosalone and carbaryl give effective control of castor semilooper (Parthasarathy and Rao, 1989). Build up of natural enemies is seriously affected by use of chemical insecticides and warrants adoption of eco-friendly pest management options like microbial and botanical pesticides. *Bacillus thuringiensis* (Bt) var. *kurstaki* is a microbial pesticide of high promise for management of lepidopteran pests (Vimaladevi *et al.*, 2001). Bt combines the twin advantages of safety to natural enemies and rapid action, causes feeding cessation of larvae within few hours after ingestion and causes mortality within 72 h. This paper presents the results of studies undertaken with DOR Bt-5, a local isolate of Bt var. *kurstaki* against castor semilooper.

Materials and methods

Isolation: DOR Bt-5 strain was isolated from soil samples collected from redgram fields in Pedaipalli village of Karimnagar district. Isolation was carried out by the method of Travers *et al.* (1987).

Multiplication of Bt: DOR Bt-5 isolate was multiplied through solid state fermentation (SSF) (Vimaladevi *et al.*, 2005).

Larval bioassays: DOR Bt-5 formulation was tested against 4 days old castor semilooper larvae and LC_{50} as well as potency were determined using a *Bt* var. *kurstaki* standard. The bioassay was conducted with the formulation at five doses, 20, 40, 60, 80, 100 mg/100 ml and with the *Bt* standard at five doses, 4, 8, 16, 32, 64 mg/100 ml.

Spray suspensions of the different concentrations of DOR Bt-5 formulation and *Bt kurstaki* standard for the various treatments were prepared using sterile 0.02% tween-80 water. Fresh castor leaves were washed and shade dried. The leaves were sprayed on both sides with the spray suspensions of each treatment and allowed to shade dry. The leaf stalks were covered with moist cotton for keeping them fresh and kept in glass jars. Ten larvae of castor semilooper were released in each jar. For control, leaves were sprayed with tween-80 water. The treated larvae were maintained at 27±1°C. Larval mortality was recorded at 48 and 72 hours after treatment. Data on larval mortality was subjected to probit analysis using the statistical package SPSS (version 8.0). Potency of DOR Bt-5 formulation was calculated using the formula

$$LC_{50} \text{ of standard} / LC_{50} \text{ test sample} \times \text{potency of standard}$$

Field testing: Field testing of DOR Bt-5 formulation against *A. janata* was undertaken in a randomized block design with seven treatments and three replications in 4.2 m x 3.6 m plots with row spacing of 60 cm. in the DOR farm on castor var. DCS-9 during the rainy season of 2009. The formulation was tested at 4 doses, *viz.*, 0.5, 0.75, 1.0 and 1.25 g/l, respectively along with Delfin - a commercial formulation of Bt @ 0.6 g/l, insecticidal check monocrotophos @ 1.5 ml/l and an unsprayed control. The formulations were suspended in water and sprayed with a conventional high volume knapsack sprayer. Incidence of *A. janata* larvae was recorded before spraying, at three and seven days after spraying from five tagged plants in each replication. Observations on natural incidence of parasites/predators were also recorded. Data were subjected to analysis of co-variance using the statistical package MSTATC.

Results and discussion

Laboratory bioassays: In the bioassays conducted with five doses of the DOR Bt-5 formulation against 4 days old larvae of *A. janata*, significant larval mortality was obtained by two days after treatment with reduction in larval numbers to 12-28 in different doses (Table 1). A similar trend was observed in larval bioassays with the *Bt kurstaki* standard (Table 2). Data subjected to probit analysis resulted in LC_{50} values of 39.63 and 13.93 mg/100 ml for DOR Bt-5 formulation and *Bt kurstaki* standard, respectively at 48 h after treatment (Table 3). The potency of DOR Bt-5 formulation was found to be 10,896 IU/mg against castor semilooper larvae.

Table 1 Mortality of 4 days old castor semilooper larvae due to DOR Bt-5 (formulation) at 48h and 72h

Dose (mg/100 ml)	No. of dead larvae (n)							
	R-1(n/10)		R-2 (n/10)		R-3 (n/10)		Total (n/30)	
	48 h	72 h	48 h	72 h	48 h	72 h	48 h	72 h
20	5	5	5	6	2	5	12/30	16/30
40	6	7	3	7	5	5	14/30	19/30
60	6	10	7	10	5	10	18/30	30/30
80	6	10	7	10	7	10	20/30	30/30
100	10	10	8	10	10	10	28/30	30/30

Table 2 Mortality of 4 days old castor semilooper larvae due to Bt standard at 48h and 72h

Dose (mg/100 ml)	No. of dead larvae (n)							
	R-1(n/10)		R-2 (n/10)		R-3 (n/10)		Total (n/30)	
	48 h	72 h	48 h	72 h	48 h	72 h	48 h	72 h
4	3	5	6	8	3	5	12/30	18/30
8	5	9	4	4	5	5	14/30	18/30
16	5	5	4	10	7	10	16/30	25/30
32	5	10	8	10	6	10	19/30	30/30
64	10	10	7	10	8	10	25/30	30/30

Table 3 Probit analysis

Sample	Hours after treatment	LC_{50} (% w/v)	Fiducial limits	Regression equation
Bt kurstaki standard	48	13.93	-3.38 - 24.70	Y - -0.27 x 0.01X
DOR Bt-5 formulation	48	39.63	23.52-50.22	Y= -0.83 x 0.02X

Field testing: Incidence of castor semilooper was first observed on 30 days old crop with 23.0 - 28.0 larvae/5 plants. The treatments were imposed at this stage. The larval number at 3 days after spray decreased to 7.0-14.0 larvae/5 plants in DOR Bt-5 treatments while the number decreased to 5.1 and 6.6 in Delfin and monocrotophos sprayed plots, respectively. Incidence in the unsprayed control however increased to 28.7 larvae/5 plants. By 7 days after spray, the larval incidence in DOR Bt-5 sprayed plots decreased significantly. The incidence in DOR Bt-5 @ 1.0 g/l decreased to 0.9/5 plants and was on par with the commercial Bt formulation Delfin as well as the insecticidal check monocrotophos (Table 4). There was a good build up of the larval parasitoid *Microplitis maculipennis* by 7 days after spray in DOR Bt-5 sprayed plots (1.3 - 4.6/plot) in contrast to the Delfin and monocrotophos sprayed plots where the parasitoid was completely absent. Castor being a dryland crop warrants use of low-cost crop protection technologies for insect pest management. DOR Bt-5 formulation with a production cost less Rs.300/kg holds great promise over the commercial Bt formulation Delfin that with a prohibitive cost of Rs.3500/kg.

Table 4 Field testing of DOR Bt-5 formulation against castor semilooper

Treatment	Larvae/5 plants			Parasitoids/plot 7 days after spray
	Before spray	3 days after spray	7 days after spray	
DOR Bt5 – 0.5 g/l	28.0	13.3	3.9	1.33
DOR Bt5 – 0.75 g/l	26.7	13.2	3.3	3.66
DOR Bt5 – 1.0g/l	27.7	10.0	0.9	1.66
DOR Bt5 – 1.25 g/l	23.0	7.8	2.1	4.66
Delfin – 0.6 g/l	25.3	5.1	0.7	-
Monocrotophos 0.05% - 1.5 ml/l	24.0	6.6	1.7	-
Unsprayed control	25.3	28.72	20.3	5.33
SEm±	-	1.6	0.69	
CD (P=0.05)	-	5.0	2.2	

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Seasonal incidence of jassid, *Empoasca flavescens* (F.) on various castor genotypes

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Abstract

In the present study, an attempt was made to study the incidence pattern of jassids, *Empoasca flavescens* (Fabricius) during the years 2007-09. Analysis of variance has showed that among the genotypes RG-3056 showed significantly lowest incidence of 7.60 /leaf followed by RG-2713, RG-2717, NBR-1 and Talap Green. But, in all genotypes the pest population was found to be above economic threshold level (ETL). The genotypes RG-563 showed significantly higher population (12.13/leaf) followed by RGCSRS1, Damalgiri Red, RG-2824 and Agia local. Environmental effect on population of jassids was very pronounced with significant interactions between years and season. The cumulative data has revealed that among the four seasons during which the study was conducted, the environmental conditions that prevailed during November were less congenial for the population build up. Whereas, among the seasons June was found to be most congenial for the population build up of jassids (13.74/leaf) followed by February (10.67/leaf) and August (9.75/leaf).

Keywords: Seasonal incidence, *E. flavescens*, castor genotypes

Introduction

India enjoys a unique distinction of being the only country in the world producing all varieties of natural silk *viz.*, mulberry, tasar, oak tasar, eri and muga. Among the commercially exploited silkworms, eri silkworm is completely domesticated multivoltine species under non-mulberry (Vanya Silk) sector that is reared throughout the year. The advent of eri culture in the country is lost into antiquity but the fact remains that it had close link with the culture and tradition of people of North-east India with the rural folk does this culture primarily to meet the domestic demand of warm clothing besides treating the pupae as a delicacy. Apart from North-east region, eri culture is also practiced in the states of West Bengal, Bihar and Orissa (Krishna Rao, 2003).

Eri silkworm, *Samia ricini* Donovan is polyphagous in nature and feed primarily on Castor, *Ricinus communis* L. Owing to its luxuriant growth due to heavy rainfall and humid atmosphere, castor plants are being infested by wide variety of insect pests. Castor crop is attacked by a number of insect-pests, of which red hairy caterpillar (RHC), semilooper, shoot and capsule borer, jassid, tobacco caterpillar, bihar hairy caterpillar, whitefly, etc., are the major ones (Rai, 1976). Jassid, *Empoasca flavescens* (Fabricius) commonly called as plant hopper infest the leaves and devitalize the crop leading to heavy yield losses. The infestation of *E. flaviscens* was proved to result in severe hopperburn symptoms due to the toxicogenic nature of the insect. Detailed studies revealed that hopperburn injury has affected the metabolism of certain varieties of castor. In the present study, an attempt was made to study the incidence pattern of jassid, over castor genotypes.

Materials and methods

The study was carried out in randomized block design at Central Sericultural Research and Training Institute, Berhampore, Murshidabad during 2007-09. Ten castor genotypes were grown in an experimental area of 30m x 42m, which is sub-divided into thirty sub-plots (4m x 6m). In each sub-plot 16 plants were grown with a spacing of 1m x 1.5m. Cultural operations were carriedout as per the recommendations made by Central Muga, Eri Research and Training Institute, Lahdoigarh. Data on the incidence of jassids was collected from five plants of each sub-plot. From each plant data was collected from five leaves. Counts were made on the number of nymphal and adult stages of jassids/leaf during morning hours. The data collected was subjected to analysis of variance.

Results and discussion

The incidence of jassids was studied as per the harvest schedule of the castor leaves for eri- silkworm rearing purpose. During the first year of the study, in June, 2007 the maximum incidence of jassids was observed in RG-2824 (21.67/Leaf) and minimum was on RG-3056 (16.33/leaf). Whereas in June, 2008 the maximum incidence was recorded with RG-553 (11.33/leaf) and the minimum was with RG-2713 (6.33/leaf). But the infestation was above economic threshold level (ETL) (3/leaf). During August, 2007, the highest incidence was observed with RG-2824 (16.94/leaf) and the lowest was with RG-3056 (5.23/leaf). In the following year, maximum population was observed in NBR-1 (11.13/leaf) and minimum was on RG-553 (5.33/leaf).

In November crop (2007), the incidence of jassids was found above ETL in all genotypes with the genotype RG553 recording the maximum with 9.4 nos./leaf and RG-3056 recording the minimum population (3.93/leaf). During the following year, Talap green and RG-2713 recorded maximum population with 4.4/leaf and minimum was recorded in Talap Green (3 nos./leaf). During the study period, this was the only season, where RG- 3056, NBR-1, Damalgiri Red and Agia local recorded the incidence level marginally nearer to ETL. During, February, 2008 the maximum incidence of the pest was observed in NBR-1 (13.54/leaf) and minimum in RG-3056 (5.53/leaf). In the following year, during the same season the highest incidence was recorded with RG CSRS-1 (14.76/leaf) and minimum with RG-3056 (6.8/leaf).

Jayaraj (2008) while studying the impact of date of sowing on the jassid infestation on three castor varieties, found that level of infestation, hopperburn symptoms and yield reduction of Dominic variety was significantly higher in the later sowings than in the earlier sowings. In the present study, jassid infestation was found on the crops during the four seasons (February, June, August and November).

The data of the present study has been subjected to analysis of variance (Anova) (Table 1 and 2). Among the genotypes RG-3056 showed significantly lowest incidence of 7.60/leaf. In the similar lines genotypes RG-2713 (8.27/leaf), RG-2717 (9.42/leaf), NBR-1 (9.80/leaf) and Talap Green (9.86/leaf) were recorded with the incidence on par with the genotype RG-3056. But, in all genotypes the pest population was found to be above ETL (3/leaf) (Table 1).

Among the genotypes RG-563 showed significantly higher population (12.13/leaf), where as the genotypes RGCSRS1 (10.54/leaf), NBR-1 (9.80/leaf), Damalgiri Red (10.79/leaf), RG-2824 (10.94/leaf) and Agia local (10.42/leaf) do not differ significantly than that of RG-563 (Table 1).

Environmental effect on population of jassids was very pronounced with significant interactions between years and season. The cumulative data has revealed that among the four seasons of crop growth, the environmental conditions that prevail during November 2008 are less congenial for the population build up of jassids during which the population was recorded nearer to the ETL (3.81/leaf). But, the cumulative data of two years for the particular season recorded the population as 5.75, which is above ETL. Whereas, among the seasons June was found to be most congenial for the population build up of jassids (13.74/leaf) followed by February (10.67/leaf), August (9.75/leaf) and November (Table 2). From this study it can be inferred that all 10 genotypes selected for this study are susceptible for jassids infestation. Accordingly extension functionaries and farmers are advised to follow recommended Integrated management practices for protecting the castor leaves from hopperburn caused by jassids.

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Table 1 Incidence of *E. flavescens* on various castor genotypes during 2007-08

Genotype	Population (no./leaf)				
	June	August	November	February	Mean
RG-3056	12.33	7.62	3.63	6.80	7.60
RG-2713	11.87	7.83	5.97	7.43	8.27
RGCSRS1	12.47	8.95	5.97	14.77	10.54
RG-2717	14.40	9.05	6.43	7.80	9.42
NBR - 1	14.57	10.89	5.80	7.93	9.80
D.RED	15.63	10.13	6.00	11.40	10.79
RG-553	14.53	9.03	6.77	18.20	12.13
T.GREEN	13.12	10.42	5.57	10.33	9.86
RG-2824	15.17	12.90	6.50	9.20	10.94
Agia local	13.30	10.70	4.83	12.87	10.42
Mean	13.74	9.75	5.75	10.67	
CD (P=0.05)		Season: 1.53	Genotypes: 2.42	SxG: NS	

Table 2 Effect of seasons on the incidence of *E. flavescens* on different castor genotypes during 2007-08

Seasons	Population (no./leaf)		
	2007-08	2008-09	Mean
Jun	18.94	8.53	13.74
Aug	10.18	9.33	9.75
Nov	7.68	3.81	5.75
Feb	10.87	10.48	10.67
Mean	11.92	8.04	
CD (P=0.05)	Year: 1.08	Season: 1.53	YxS: 2.17

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Role of predisposing factors on the development of root rot of castor *Macrophomina phaseolina* (Tassi) Goid

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Abstract

Root rot caused by *Macrophomina phaseolina* (Tassi) Goid is one of the major diseases of castor (*Ricinus communis* L.) that occurs in a very destructive form in Saurashtra region of Gujarat. There are many predisposing factors that enhance the development of diseases which in later stage reaches in an epidemic form. The present study on the comparative efficacy of inoculum levels in inducing root rot disease in castor indicated that as the levels of inoculum increased from 10 to 100 g the root rot disease incidence also increased. The young plants of 15-60 days of age were comparatively more susceptible to root rot under pot conditions. As the age increased above 60 days, the trend of disease incidence decreased i.e., from 78.75 to 15% at seven days after inoculation. The development of disease decreased significantly as the plants attained the age of 105 days and above. The period of incubation was also equally important in the development of disease. Therefore, inoculum load and age of the plant along with incubation period played vital roles on development of castor root rot.

Keywords: Castor, *Macrophomina phaseolina*, root rot and predisposing factors

Introduction

The castor oil plant (*Ricinus communis* L.) is generally grown for the economic importance of its oil yielding seeds. Though castor production in India is more than world average, there are several production constraints *viz.*, moisture stress, insect pests and several diseases that dominate in castor growing areas of Andhra Pradesh, Gujarat and Rajasthan. Root rot disease caused by *Macrophomina phaseolina* (Tassi) Goid is considered to be the most serious castor bean pathogen in dry and warm conditions. This has been known to occur in a very severe form in Saurashtra region of Gujarat under stress conditions mainly at later stage of the crop. It has been reported that the disease incidence increases with an increase in inoculum level as well as the age of the plants (Sunder *et al.*, 1996 and Kanakamahalakshmi *et al.*, 1999). Studies by Hooda and Grover (1988) have revealed that an increase in inoculum quantity of *M. phaseolina* from 1.25 to 2.00 g/800 g soil results in a progressive increase in the mortality of seedling in mungbean. The maximum levels of infection due to *M. phaseolina* observed in host plant, varies with their age as 20 to 65 days in urdbean (Abbaiah and Satyanarayan, 1990), 60 days in jute (Pan *et al.*, 1981) and 45 days in castor (Maiti and Raoof, 1984). Since castor root rot is a very serious problem, a study on the predisposing factors, which enhances its development is very much essential for the management of this disease.

Materials and methods

To know the effect of inoculum levels on disease development, different levels of inoculum (prepared in sorghum-sand-medium; SSM) of *M. phaseolina viz.*, 0, 10, 20, 40, 60, 80 and 100 g were tested in pots (15 cm diameter) containing sterilized soil by soil inoculation method in a completely randomized block design with four replicates. Five seeds of castor hybrid GCH-4 were sown in each pot. Plants kept as control (zero level) were grown in sterilized soil and they were free from inoculum. The treated plants were observed regularly for the appearance of the disease and the per cent disease incidence was calculated by using the standard formula.

Another experiment was conducted in pots to know the most susceptible age for root rot disease. Plants of different age groups *viz.*, 15, 30, 45, 60, 75, 90, 105, 120, 135 and 150 days were grown for inoculation by sowing five seeds of castor hybrid (GCH-4) in pots (15 cm diameter) for the different treatments at various intervals. The plants of different age groups were inoculated by stem tape inoculation method in which the hypocotyl region of the plants was superficially wounded by peeling the epidermis at 2 cm above the soil surface. A mycelial disc of 4 mm in diameter was placed against the wound and covered it with cellophane tape. Control plants were wounded and were inoculated with a sterile PDA disc. Each treatment was replicated four times. The plants were observed regularly after inoculation for the appearance of the disease and per cent disease incidence was calculated by using the standard formula.

Results and discussion

Effect of inoculum load on disease incidence caused by *M. phaseolina*: In this experiment, the initial symptom of drooping of leaves started appearing on 20th day after inoculation in pots where 100 g SSM inoculum was applied. Thereafter, on 28th day after inoculation an average of 70% plants wilted in pots having 100 g inoculum level while in lower concentrations *viz.*, 10, 20 and 40 g only very few plants (35, 40 and 45%) wilted (Table 1).

The increase in inoculum density of soil borne plant pathogen usually results in a greater intensity/severity of disease. As the levels of inoculum increased from 10 to 100 g in a pot, there was a progressive increase in root rot disease of castor. Hooda and Grover (1988) opined that an increase in inoculum quantity of *M. phaseolina* from 1.25 to 2.00 g/800 g soil results in a progressive increase in seedling mortality in mungbean. According to Baker (1971) the increase in inoculum density of soil borne plant pathogen usually results in greater disease intensity until a plateau is reached. The pathogen fails to induce wilt disease at lower levels of inoculum concentrations (Desai and Dange, 2003). In root rot also the disease incidence was significantly influenced by different inoculum concentrations. It is confirmed that castor root rot is positively correlated with increasing inoculum concentration.

Effect of plant age on disease incidence caused by *M. phaseolina*: The young plants (between 15-60 days old) appeared to be comparatively more susceptible. The infected plants initially showed the symptoms of drooping of leaves within 5-6 days and later produced pycnidia on the infected stem, which finally resulted to the death of the plants. As the age increased above 60 days, the trend of disease incidence decreased i.e., from 78.75 to 15.00% (7 DAI). All the plants up to 60 days of age wilted due to root rot on 15 days after inoculation. Moreover, the disease incidence decreased as the age increased above 90 days. There was significant decrease in the development of disease when the plants attained the age of 105 days and above (Table 2). The results also indicated that the period of incubation was also equally important in the development of disease. As the incubation period increased from 15 to 30 days the disease development also increased correspondingly, irrespective of the age of plant.

Thus, the castor crop is susceptible to root rot at all growth stages under favourable environmental and soil conditions the disease incidence decreased as the age increased above 90 days. Similar findings have been reported for castor wilt (Desai and Dange, 2003) wherein the disease incidence has been negatively correlated with the age of seedlings. Kanakamahalakshmi *et al.* (1999) have also observed in castor that the disease incidence increases with an increase in inoculum level. While testing the susceptibility of cowpea against *M. phaseolina* at different stages of plant growth, Ratnoo and Bhatnagar (1993) observed severe infection (> 68%) on the plants up to the age of 45 days, and its gradual decrease thereafter with an increasing age of the plants.

Therefore, the present investigation indicated that inoculum load, age of the plant and period of incubation are the major predisposing factors which influence the development of castor root rot. Moreover, this information is in conformity with the earlier findings on various crops *viz.*, urdbean, cotton, jute and groundnut.

Table 1 Influence of inoculum load on development of root rot

Different levels of inoculum/pot (g)	Disease incidence* (%)
10	35.0 (31.6)
20	40.0 (33.8)
40	45.0 (35.4)
60	50.0 (36.9)
80	60.0 (39.6)
100	70.0 (42.1)
Control	0.0
SEm±	1.8
CD (P=0.05)	5.4
CV (%)	9.9

Average of 4 replications

Table 2 Influence of age of plant on development of root rot

Different age of plant (days)	Disease incidence (%)	
	7 days after inoculation*	15 days after inoculation*
15	68.7 (56.2)	100 (90.0)
30	72.5 (58.5)	100 (90.0)
45	75.0 (60.2)	100 (90.0)
60	78.7 (62.5)	100 (90.0)
75	63.7 (53.0)	95.0 (83.3)
90	57.5 (49.3)	90.0 (76.7)
105	55.0 (47.8)	88.7 (75.8)
120	40.0 (39.2)	83.7 (69.2)
135	21.2 (27.4)	72.5 (58.5)
150	15.0 (19.9)	68.7 (56.2)
SEm±	2.8	4.8
CD (P+0.05)	8.3	14.0
CV (%)	12.1	12.4

Values in parentheses are Arscine transformation

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Screening of castor germplasm for identification of resistant sources against *Botrytis* gray mold

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Abstract

***Botrytis* gray mold is a major disease of castor causing extensive economic loss during cyclonic weather conditions as the infection spreads quickly affecting entire crop in short time. Identification of host resistance is the best and cheapest method of disease management. Studies were conducted to identify germplasm accessions resistant to *Botrytis* gray mold under artificial epiphytotic conditions in greenhouse and field. Of the 423 accessions screened for resistance against *Botrytis* gray mold under artificial epiphytotic conditions in the field, 24 entries *viz.*, RG-2866, 2033, 1009, 252, 1340, 198, 128, 127, 180, 177, 65, 18, 111, 83, 77, 209, 204, 236, 275, 269, 237, 256, 288 and 1149 showed resistant reaction (<10% capsule infection) and 6 entries *viz.*, RG- 1759, 2822, 3013, 269,1934 and 204 were disease free. Four lines *viz.*, RG-1759, 3013, 269 and 1934 were disease free even under artificial inoculation conditions in greenhouse.**

Keywords: *Botrytis* gray mold, germplasm, resistant sources

Introduction

Castor (*Ricinus communis* L.) is a species of flowering plant belonging to monotypic genus. It is an important oilseed crop grown in arid and semi-arid regions of India. Owing to the growing demands for the castor oil worldwide, the area of cultivation for castor has been increased to 8.01 lakh ha and production of 1115 thousand tonnes during 2008-09. India is the leading producer of castor (with over 60% of global yield) followed by China and Brazil. *Botrytis* gray mold is one of the major diseases of castor causing nearly 70% yield loss (AICRP, 2007 and 2009). In India, the disease was first noticed in Karnataka (Anonymous, 1921) and is serious in states of Andhra Pradesh and Tamil Nadu. In 1987 the disease occurred in endemic form in Andhra Pradesh (Moses and Reddy, 1989).

Botrytis gray mold caused by *Botrytis ricini* Godfrey (Godfrey, 1923) is mostly confined to spikes/raceme. Under favourable conditions disease rapidly spreads to stems and leaves. Continuous wet weather and high humid conditions are highly conducive for the disease development (Moses and Reddy, 1989). The spores from infected capsules are readily disseminated by the wind and splashing rainfall causing secondary infection. Once the inoculum establishes on the host plant within 5-7 days the whole spike rots leading to complete loss. Thus the management of the disease is difficult if not controlled at an early stage of disease incidence. Besides, genetic sources resistant to the disease are lacking and other remedial measures were not effective. However morphological traits of castor that would assist the growth of the fungus were identified (Thomas and Orellane, 1964).

Identification of host resistance is one of the viable options for disease management. Large numbers of germplasm accessions available at Directorate of Oilseeds Research (DOR) were screened in field and greenhouse under artificial epiphytotic conditions using fogger systems. Under semi-arid conditions, sprinkler irrigation provides the necessary microclimatic conditions for the development of the disease (Lomas, 1991). The timing of irrigation in relation to moisture provided by rainfall or dew is critical for the disease incidence. In this paper castor germplasms were screened against *Botrytis* gray mold in an attempt to identify the resistant sources for the disease.

Materials and methods

Four-hundred-and-twenty-three castor germplasm accessions were screened against *Botrytis* gray mold along with the susceptible check DCS-9 in the field at DOR farm, Hyderabad during 2009-10. Each accession was planted in a single row of 4.5m at 90 cm x 45 cm spacing on 2nd July 2009. Foggers with a flux of 16 l/hr were fitted throughout the field to provide the artificial epiphytotic conditions. Each four way sprinklers fitted to the foggers covered an area of 1m and the pressure (40-45 kg/cm2) produced water droplets of 70 microns size. Sprinkler irrigation was provided at the capsule development stage for a duration of 10-30 min to maintain humidity above 90%, that favours the infection. Weather parameters *viz.*, temperature, relative humidity, number of rainy days, rainfall, sunshine and wind speed were recorded upto standard week 40 to correlate the disease incidence with the existing environmental conditions. Botrytis incidence was scored on 0-9 scale by recording the percentage of capsules infected in secondary spikes.

The resistant entries were further screened *in vitro* using detached spike technique in greenhouse conditions (DOR, 2000). Healthy spikes collected from the field were placed in 2% sucrose solution in 250 ml Erlenmeyer flasks. Inoculum of *Botrytis* ricini was prepared by scraping a well sporulated plate in distill water and spore density was adjusted to 106/ml and spore suspension was sprayed on to the healthy spikes. The spikes were maintained at an ambient temperature of 28°C and 90% humidity for 7 days in greenhouse using fan pad cooling system. Periodic misting was provided three times a day using fogging system at a rate of 1-3 min/hour to maintain the water droplets on the spikes/raceme, favouring the growth of the fungus. Three replicates were maintained for each accession and the disease incidence was scored by recording the percentage of capsules infected.

Results and discussion

Castor being a monotypic genus, search for resistance in other species in not feasible. Several plant breeders tried to identify resistant sources against *Botrytis* gray mold since the causative organism, *Botrytis ricini* is host specific (Raoof and Yasmeen, 2006). Thus identification of the disease resistance in the germplasm of castor was attempted. At DOR, 423 castor germplasms were screened for resistance against *Botrytis* gray mold under artificial epiphytotic conditions in field and greenhouse. Disease incidence was observed during the first week of September, 2009 when congenial weather conditions coincided with the capsule development stage of secondary spikes of castor. During this week the average temperature was 25.7°C, RH- 93 and 4 continuous rainy days, rainfall 43 mm, sunshine 1.9 hr and wind speed 7.5 km/hr. These conditions were highly favourable for the development and spread of the disease. (Raoof and Yasmeen, 2006).

Among 423 germplasm accessions disease incidence was scored on 349 as 44 lines did not germinate and 32 lines were of late duration. Screening of the accessions both under field conditions resulted in identification of twenty four resistant and six disease free lines (Table 1). Four disease free lines *viz.*, RG- 1759, 3013, 269 and 1934 were not infected even under greenhouse conditions. Disease incidence in the resistant accessions ranged from 3 to 10% while it was 11 to 100% in other accessions and 90% in susceptible check DCS-9. Of the four disease free accessions, RG-269 was non-spiny (dwarf) and the other 3 lines *viz.*, RG-1759, 3013 and 1934 had spiny capsules. Furthermore these lines had divergently branched, loose capsules. These identified accessions may be exploited in disease resistance breeding programme for incorporating resistance to *Botrytis* gray mold.

Table 1 Screening of germplasm for resistance to *Botrytis* gray mold (*Botrytis ricini*)

Disease incidence (%)	Germplasm accessions
Disease free (6)	RG-1759, 2822, 3013, 269, 1934, 204
Resistant: : 1-10% capsules infected (24)	RG-2866, 2033, 1009, 252, 732, 1340, 198, 128, 127, 180, 177, 65, 18, 111, 83, 77, 209, 204, 236, 275, 269, 237, 256, 288, 1149
Moderately resistant: 11-25% capsules infected (121)	RG-2818, 1163, 2046, 3063, 2902, 892, 1111, 2681, 2944, 784, 328, 61, 1978, 1621, 905, 2046, 43, 3102, 119, 148, 146, 1507, 1654, 237, 190, 183, 182, 181, 39, 38, 36, 168, 164, 2483, 1354, 2810, 551, 87, 88, 92, 191, 47, 42, 2035, 96, 193. 196, 126, 125, 122, 21, 25, 29, 22, 2902 845, 68, 173, 170, 79, 80, 81, 85, 86, 58, 1852, 216, 217, 292, 257, 263, 268, 208, 205. 203, 201, 227, 226, 225, 224, 223, 3217, 2706, 3120, 1998, 281, 279, 235, 272, 243, 249, 250, 253, 3067, 2894, 3102, 2902, 613, 2509, 225, 3043, 2712, 220, 1313, 2033, 2550, 1980, 2520, 1611, 3073, 2944, 709, 607, 3120, 1976, 3224, 2958, 784, 82, 860, 2645
Susceptible: 26-50% capsules infected (123)	RG-1369, 1696, 3283, 289, 1406, 2618, 3037, 607, 790, 467, 3067, 565, 178, 1521, 2014, 2195, 2457, 294, 233, 589, 159, 273, 156, 189, 188, 184, 31, 134, 141, 144, 58, 52, 89, 90, 50, 49, 45, 41, 1981, 2473, 97, 192, 194, 199, 200, 123, 24, 74, 66, 268, 16, 14, 2022, 2269, 78, 211, 212, 214, 215, 218, 2429, 295, 294, 292, 291, 290, 289, 259, 260, 265, 207, 202, 232, 231, 3195, 2874, 288, 286, 285, 284, 282, 280, 278, 273, 271, 270, 244, 240, 245, 246, 247, 2879, 3164, 3744, 790, 1009, 1707, 2717, 3283, 1759, 1364, 2818, 252, 3198, 2958, 2991, 3007, 3122, 2605, 3224, 2970, 3037, 1265, 3116, 2709, 2894, 1265, 898, 872, 1151, 426, 848, 1435
Highly susceptible: >50% capsules infected (73)	RG-2874, 845, 2939, 3088, 673, 3073, 1880, 558, 1122, 415, 100, 152, 387, 32, 37, 165, 163, 136, 137, 860,139, 3217, 56, 55, 53, 162, 1627, 94, 1554, 1709, 489, 1114, 48, 46, 44, 40, 969, 2582, 1707, 408, 197, 133, 130, 129, 70, 67, 63, 174, 19, 15, 76, 221, 1340, 296, 267, 206, 229, 254, 242, 248, 251, 2685, 565, 1696, 1627, 1234, 2729, 135, 467, 2487, 732, 33, 140

Number of castor accessions were given in parentheses

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Evaluation of advanced breeding material of castor (*Ricinus communis* L.) for *Fusarium* wilt resistance

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Abstract

A field trial was conducted during 2006-07 to evaluate 44 entries including initial/advanced varietal trial, initial hybrid trial and advance hybrid trial in wilt sick plot. Resistant (Haritha) and susceptible (Kranti) checks were sown after every 5 test entries. Advanced breeding material was sown in a single row with 5m length with 17 plants at 45 cm x 30 cm spacing. Initial inoculum load of the wilt pathogen was 1.64 x 10^3 cfu/g of soil before the start of the experiment and it was increased to 1.83 x 10^3 cfu/g of soil at the end of the experiment. Out of 36 entries screened seven entries i.e., DCS-99, DCS-101, DCS-100, DCS-102, DSP-018, DCH-970 and SHB-758 were resistant under wilt sick conditions up to 150 days after sowing.

Keywords: Castor, screening, advanced breeding material, *Fusarium* wilt

Introduction

Castor wilt caused by *Fusarium oxysporum* f. sp. *ricini* is one of the principal yield limiting factors in the production of castor in the major castor growing regions in India (Anonymous, 1998). The disease can be managed to a certain extent by fungicide seed treatment and with use of bio-control agents. The role of monoculture in increasing the disease incidence after each subsequent crop with reduction in yield is well documented (Merwe, 1979). Identifying resistant cultivars to these fungi in germplasm collection would be the most practical way to control this disease. The present study was undertaken to identify source of resistance in castor germplasm for *Fusarium* wilt.

Materials and methods

Field screening of the genotypes was conducted during 2006-07 in the wilt sick plot of Regional Agricultural Research Station, southern telangana zone (STZ) of Andhra Pradesh, Palem, Mahaboobnagar district. Advanced breeding material was obtained from Directorate of Oilseeds Research, Rajendranagar, Hyderabad. A total of 36 advanced breeding material were evaluated in a highly wilt sick plot with Kranti as susceptible check and Haritha as resistant check. Advanced breeding material were sown in a randomized block design with three replications in a single row with 5m length at 45 cm x 30 cm spacing. Resistant and susceptible checks were sown after every five test entries. The inoculum load of the wilt pathogen was estimated before sowing and after harvest of the crop (Sharma and Singh, 1973) and expressed as colony forming units/g of soil (cfu/g). Inoculum load of sick plot was maintained by adding *Fusarium* culture mass multiplied on sorghum seeds at regular intervals of 30 days and maintained through out the season. Disease incidence (number of infected plants) was monitored periodically at 30 days intervals up to 150 days. Wilt incidence was calculated using the formula.

$$\text{Wilt incidence (\%)} = \frac{\text{No. of plants showing wilt incidence}}{\text{No. of plants germinated}} \times 100$$

Genotypes showing < 20% wilt incidence were categorized as resistant and others as susceptible to the disease.

Results and discussion

Wilt caused by *Fusarium oxysporum* f.sp. *ricini* is one of the major diseases in castor characterized by discolouration of hypocotyles, loss of turgidity of top leaves and marginal necrosis at the seedling stage. Adult plants show gradual yellowing, sickly appearance of leaves followed by necrosis, browning of xylem tissues and irreversible wilting with bending of apical leaves and branches. It was first reported in India and the wilt incidence as high as 85-90% was reported in wilt endemic areas of various castor growing states (Nanda and Prasad, 1974). Even the leading wilt resistant castor hybrid GCH-4 turned out to be susceptible to *Fusarium* wilt with 90% wilt incidence in endemic areas (Patel *et al.*, 1991). Hence there is a need for identification and incorporation of new source of wilt resistance in breeding material for development of resistant cultivars.

Initial inoculum load of the wilt pathogen was found to be 1.64 x 10^3 cfu/g of soil before the start of the experiment and it was increased to 1.83 x 10^3 cfu/g of soil at the end of the experiment. No significant difference in the colony count was recorded at different locations of the plot. Among 36 entries screened, seven entries *viz.*, DCS-99, DCS-101, DCS-100, DCS-102, DSP-018, DCH-970 and SHB-758 (Table 1) were resistant under highly wilt sick conditions up to 150 days after sowing. Wilt incidence in these accessions ranged from 0 to 20%, where as in the susceptible check Kranti it was 41.2% and 7.9% in the resistant check Haritha and all remaining accessions showed more than 20% wilt incidence (ranged from 37.3 to 76.5%) and categorized as susceptible to this disease.

Though the wilt symptoms appeared thirty days after sowing (DAS), the incidence was less up to 60 DAS then slowly, the upward trend of increase in wilt incidence was noticed. Out of 36 entries evaluated, 16 entries were resistant to wilt (< 20%) after 90 days after sowing. Further, the number of entries resistant to wilt was declined to eight i.e., 50% reduction was noticed at 120 DAS, as the age of the plant increases, the resistance to wilt was decreased. After 150 days of sowing only seven entries exhibited resistance to wilt disease.

Thus, it can be concluded that these resistant advanced breeding material can be used as donors in the breeding programme for the development of *Fusarium* wilt resistant variety and hybrid in castor.

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Table 1 Evaluation of castor genotypes against *Fusarium* wilt resistance in sick plot

Entry	Wilt incidence(%)* DAS				
	30	60	90	120	150
JI-342	7.9	19.6	29.4	47.1	52.9 (46.7)
DSP-222	3.9	5.9	19.6	25.5	39.2 (38.8)
PSC-111	5.9	7.9	19.6	29.4	37.3 (37.6)
SKI-304	3.9	9.8	21.6	43.1	60.8 (51.3)
SKI-294	11.8	15.7	19.6	35.3	47.1 (43.3)
DCS-99	0.0	2.0	3.9	9.8	11.8 (19.7)
DCS-101	2.0	2.0	9.8	13.8	19.6 (26.2)
DCS-104	7.9	11.8	19.6	31.4	49.0 (44.4)
KC-1	5.9	11.8	17.7	29.4	49.1 (44.4)
KC-163	5.9	9.8	13.8	23.5	37.3 (37.4)
DCS-100	0.0	3.9	7.9	7.9	13.8 (21.7)
DCS-102	0.0	0.0	5.9	9.8	15.7 (23.3)
DSP-018	0.0	2.0	3.9	9.8	17.6 (24.6)
SKI-291	5.9	9.8	27.4	31.4	39.2 (38.8)
SKI-299	13.8	15.7	21.6	33.3	45.1 (42.2)
PCH-883	13.8	23.5	37.3	45.1	58.8 (50.1)
RAJA-5	13.7	37.3	58.8	58.8	64.7 (53.6)
DSP-999	5.9	11.8	33.3	41.2	47.1 (43.3)
S-555	13.7	27.4	29.4	35.3	41.2 (39.9)
SVHC-235	3.9	5.9	13.8	19.6	47.1 (43.3)
SNSCH-35	13.7	21.6	31.4	45.1	52.9 (46.7)
JHB-938	3.9	15.7	29.4	39.2	47.7 (43.3)
JHB-918	3.9	9.8	29.4	39.2	43.2 (41.0)
JHB-887	9.8	13.8	21.6	37.3	52.9 (46.7)
RHC-173	3.9	11.8	29.4	31.4	41.2 (39.9)
RHC-170	5.9	13.8	33.3	35.3	47.1 (43.3)
SHB-813	11.8	17.7	35.3	45.1	64.7 (53.6)
SHB-808	11.8	21.6	27.4	41.2	50.9 (45.6)
SHB-793	2.0	9.8	19.6	37.3	49.1 (44.5)
DCH-970	0.0	1.9	3.9	5.9	11.8 (19.7)
NBCH-205	9.8	19.6	25.5	47.1	60.7 (51.3)
Maharaja	1.9	3.9	7.8	23.5	47.1 (43.3)
JHB-927	15.7	17.7	35.3	58.8	76.5 (61.7)
SHB-765	1.9	7.9	25.5	47.1	52.9 (46.7)
SHB-758	0.0	0.0	3.9	5.9	15.7 (23.3)
Kranti (S)	13.8	17.7	31.4	41.2	41.2 (39.9)
Haritha (R)	0.0	0.0	0.0	5.9	7.9 (18.1)
				SEm+	2.3
				CD (P=0.05)	6.5
				CV (%)	10.8

*Mean of three replications; *Figures in the parenthesis are angular transformed values; S = Susceptible check; (R)=Resistant check

Activity of insectivorous predatory birds in castor ecosystem

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Abstract

Castor semilooper (*Achaea janata* Linn.), tobacco caterpillar (*Spodoptera litura*, Fabricius)), red hairy caterpillar (*Amsacta* spp.) and castor shoot and capsule borer (*Conogathus punctiferalis*, Guenee)) are major insect pests of castor in the southern part of India. Several parasitoids insect predators and insectivorous predatory birds are effective in suppressing perpetuation of insect pests in castor ecosystem. Cattle egret (*Bubulcus ibis*), House crow (*Corvus splendens*), Black drongo (*Dicrurus adsinilis*) and Indian myna (*Acridotheres tristis*) were actively predating on resting stages of insects pests and soil insects during summer ploughing, field operations and inter culturing in the castor crop. Indian myna, Black drongo, House crow, Green bee eater (*Merops orientalis*), Crow pheasant (*Centropers sinensis*), Hoopoe (*Upupa epoops*) and Large grey babbler (*Trudoides malcolmi*) were actively predating on grown up larvae of *A. janata* and *S. litura* by frequently using dried profuse tree branches erected as bird perches during seedling and vegetative stage of the crop compared to sorghum and castor plant as live perches but some of the birds like Indian myna, Black drongo, Green bee eater, Crow pheasant and Large grey babbler were found predating on *Conogathus punctiferalis* (Guenee) larvae using perches made of tree branches, tall sorghum plants and castor as live perch in the reproductive stage of castor crop. Black drongo and Indian myna were the predominant predatory birds which used bird perches frequently while predating on *A. janata*, *S. litura* and *C. punctiferalis* larvae in castor ecosystem.

Keywords: Castor, insect pests, insectivorous predatory birds

Introduction

In Andhra Pradesh, castor crop is grown under rainfed condition where there are several production constraints. Among biological constraints defoliators like castor semilooper (*Achaea janata* Linn.), tobacco caterpillar (*Spodoptera litura* (Fabricius)), red hairy caterpillar (*Amsacta* spp.) and castor shoot and capsule borer (*Conogathus punctiferalis* Guenee) are of greater economic importance in the southern part of India (Basappa, 2003). Castor insect pests are attacked by an array of natural enemies like egg and larval parasitoids, insect predators, spiders and several insectivorous predatory birds in nature. Though these predatory birds along with other natural enemies exert greater biological resistance in the succession of different pests in the castor ecosystem from pre sowing till harvesting there is not much information on the activity and predatory behaviour of these birds which play very important role as biological control agents in the integrated management of castor pests. Hence investigations were initiated to study the activity of insectivorous predatory birds in the traditional castor growing areas of Andhra Pradesh

Materials and methods

Investigations were carried out to study the activity and predatory behaviour of common birds in the castor ecosystem in the castor fields of one farmer each from four villages (Kandkur, Mohammad Nagar, Nednoor and Debbadguda) in Kandakur mandal and one village (Tummalur) under Maheswaram mandal under Maheshwaram water shed area of Ranga Reddy district, Andhra Pradesh during 2001-02 and 2002-03. Castor crop was grown in an area of four acres by each farmer following recommended agronomic practices. In one acre five dried and profuse tree branches and tall local sorghum variety as mixed crop served as bird perches to attract insectivorous birds. In one acre each, profuse tree branches alone and tall local sorghum variety as mixed crop alone served as bird perches to attract insectivorous birds, respectively. In another one acre, area bird perches were not used. The observations were recorded on activity of predatory birds and their behaviour during pre sowing and at different growth stages (seedling, vegetative and reproductive stages) of the crop in both the years. Activity of different predatory birds during morning (600-1000 hrs), afternoon (1100-1400 hrs) and evening (1500-1800hrs) were recorded at different growth stages.

Results and discussion

The activity of common insectivorous birds and their predatory behaviour in the castor ecosystem was recorded at pre sowing and different phenological stages of castor crop is presented below (Table 1).

Pre sowing period: During summer ploughing cattle egret (*Bulbulus ibis* boddaot) population was relatively more (47.15%) compared to Indian myna, *Acridotheres tristis* (L) (28.49%) and crow, *Corvus splendens* Vieillot (24.36%) which were found actively predating insects and resting stages by running behind the plough. Black drongo (*Dicrurus adsinilis* Blyth) was also active in predating live insects and resting stages in limited number.

Seedling stage: When there was high population of castor semilooper (*A. janata*) on seedlings (below 30 days old crop) Indian myna was predating on grown up larvae at the ground level during morning hours (600-1000 hrs) other wise it was predating in pairs by using bird perches during afternoon (1100-1400 hrs) and evening (1500-1800 hrs). House crow also was predating on grown up larvae of *A.janata* in the similar way using ground habitat other wise they predate individually using bird perches. Black drango was very active in predating grown up larvae of semilooper with aerial predatory habit during morning and evening. The nature of visit was solitary and regular and it used bird perches more frequently among all the predatory birds. Green bee eater (*Merops orientalis*) used to visit regularly in pairs whereas Large grey babbler in flocks and were found predating grown up larvae using bird perches during morning and evening. During interculturing cattle egret, crow and Indian myna activity was observed for limited period. Most of the birds used bird perches made out of dried and profuse tree branches compared to sorghum and castor crop itself as live perches.

Vegetative stage: During vegetative stage Black drongo, Indian myna, Green bee eater, Grey babbler, House crow, Hoopoe, Crow pheasant were major predators among predatory birds visited castor eco system regularly and were predating on grown up larvae of *A. janata* and *Spodoptera litura*. Maximum activity was noticed during morning hours (600-1000 hrs) followed by evening hours and least activity was observed during afternoon. House crow, Hoopoe and Crow pheasant used bird perches made of tree branches and rarely used live perches because of higher body weight compared to Black drango, Indian myna, Green bee eater, Grey babbler which used bird perches made of tree branches in addition to tall sorghum and castor crop itself as live perches. Black drongo was major predator among predatory birds visited castor eco system regularly

Reproductive stage: Activity of insectivorous birds was maximum during morning and evening hours. Indian myna, Black drongo, Green bee eater, Crow pheasant and Large grey babbler were found predating on *Conogathus punctiferalis* (Guenee) larvae using perches made of tree branches, tall sorghum and castor itself as live perch in the reproductive stage. Black drongo and Indian myna were the predominant predatory birds which used bird perches frequently while predating on *A. janata*, *S. litura* and *C. punctiferalis* larvae in castor ecosystem. Among all the predatory birds Black drongo was very active and it was frequently using bird perches for predating on capsule borer (*C. punctiferalis*) clearing webbed material. Indian myna and Green bee eater were also found predating on castor capsule borer.

Maximum activity of insectivorous birds was noticed on castor crop with both bird perches made of tree branches and tall local sorghum variety as mixed crop followed by profuse tree branches alone at seedling, vegetative and reproductive stage which might be due to presence of good number of bird perches which helped to attract maximum insectivorous birds. Tall local sorghum variety as mixed crop alone served as bird perches to attract insectivorous birds during vegetative stage and reproductive stage only and it was not effective during seedling stage as it was not able attract birds. Castor crop with out bird perches had less activity of birds in the seedling and vegetative stage but in the reproductive stage activity of birds slightly increased as castor itself served as live perch.

Among all the predatory birds observed in the castor ecosystem, Black drongo was regular from pre sowing till harvesting of the crop in predating major insect pests. The predatory efficiency was very high with Black drongo compared to other predatory birds. The bird perches were efficiently and frequently used by this bird compared to others. Farmers used bird perches in other crops like paddy, cotton, vegetables, fruits and flower crops also after observing increase in bird activity in castor. Integrated pest management (IPM) modules involving crop rotation of castor with sorghum, summer ploughing, use of wilt resistant variety Jyoti, hand picking and destruction of egg masses and early stage larvae of tobacco caterpillar and hairy caterpillars, use of NSKE (5%)/ need based insecticides, no cost or low cost bird perches made of dried profuse branches of trees (15/ha) to attract insectivorous birds was effective in keeping pest population below economic threshold level in castor ecosystem Bio intensive IPM (BIPM) module was relatively safer to natural enemies compared to insecticide intensive IPM modules and Non IPM modules. In all the integrated pest management modules activity of insectivorous birds was more due to use of bird perches compared to non integrated pest management modules where bird perches were not used (Basappa, 2006; 2007 and 2009). Several insectivorous birds are also reported as predators of insect pests of castor in Gujarat (Parasharya *et al.*, 1988).

In the castor ecosystem predatory birds play very important role as one of biological control agents in the biologically based integrated pest management approach for maintaining ecological balance and sustainable production of castor. There is a need for reducing toxic stress in the environment which is essential for survival of predatory birds and other beneficial organisms apart from creating awareness among farmers to use no cost or low cost bird perches like dried profuse tree branches and growing crops which serves as live perches to attract predatory birds to keep pest population below economic threshold level in the castor ecosystem.

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Table 1 **Activity of insectivorous predatory birds in castor eco system**

Name of the bird	Predatory habit	Nature of visit	Active period
Cattle Egret (*Bubulcus ibis*)	Ground	Gregarious (Up to 67 birds)	Active during summer ploughing, field operations and inter culturing of crop. Less active in standing crop and occasionally use bird perches.
House Crow (*Corvus splendens*)	Ground	Gregarious (Up to 30 birds) and Individual	Active during summer ploughing and field operations. Predate on grown up larvae of castor semilooper during out break of the pest. Often use bird perches. Active during morning and evening.
Indian Myna (*Acridotheres tristis*)	Ground Aerial	Gregarious Pairs (Up to 40 birds)	Active during summer ploughing, predate on exposed resting stages of pests. Predate on castor semilooper, capsule borer and *Spodoptera litura* during out break of the pest. Frequently use bird perches. Active during morning and evening.
Black Drongo (*Dicrurus adsinilis*)	Aerial	Solitary Regular visitor	Actively predate on different pests from pre sowing till harvest and frequently use bird perches. Predate on castor semilooper, *S. litura* and capsule borer larvae apart from resting stages exposed during summer ploughing. Active during morning and evening.
Green bee eater (*Merops orientalis*)	Aerial	Pairs Regular visitor	Seedling stage till maturity. Use bird perches. Predate on castor semilooper, *S. litura* and capsule borer. Some times predate Hymenopteran beneficial organism.
Hoopoe (*Upupa epoops*)	Ground	Single and Pairs	Predate on castor semilooper and *S. litura* and other insects, grubs and pupae.
Large Grey Babbler (*Trudoides malcolmi*)	Ground Aerial	Gregarious (Up to 10 birds)	Predate on castor semilooper, *S. litura* and capsule borer. Often uses bird perches. Active morning till evening.
Crow pheasant (*Centropers sinensis*)	Ground Aerial	Solitary Regular visitor	Predate on castor semilooper, *S. litura* and capsule borer. Often uses bird perches. Active during morning and evening

Reaction of castor cultivars to *Botrytis* grey mold

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Abstract

***A total of eight castor cultivars viz.*, DCH-519, GCH-4, GCH-7, DCH-177, Haritha, DCS-107, DCS-9 and 48-1 were screened against the grey mold of castor caused by *Botrytis ricini* under field conditions at Directorate of Oilseeds Research, Hyderabad during July-September, 2010. During the period the disease incidence was severe due to highly congenial weather with mean maximum temperature of 29.4°C and maximum relative humidity of 90.6%. Out of 8 cultivars screened against *Botrytis ricini*, six cultivars i.e., DCH-519, GCH-4, GCH-7, DCH-177, Haritha and DCS-9 showed disease incidence ranging from 39.7-50.3% and 48-1 recorded lowest disease incidence of 28.1%. Highest disease incidence was recorded in var. DCS-107 (69.5%). Even under highly favourable conditions for grey mold development, the var. 48-1 has showed lowest disease incidence due to its non-spiny nature of the capsules.**

Keywords: Castor, *Botrytis ricini*, reaction

Introduction

Castor (*Ricinus communis*) is an important oilseed crop grown in India. The area of cultivation under castor crop is 8.01 lakh ha with a production of 11.25 lakh t during 2008-09. India is the leading producer of castor (with over 60% of global production) followed by China. *Botrytis* grey mold is one of the major diseases of castor and has a potential to cause nearly 70% yield loss (AICRP, 2007 and 2009). In India the disease was first recorded in Karnataka state (Anonymous, 1921) and is serious in states of Andhra Pradesh and Tamil Nadu. In 1987 the disease occurred in epidemic form in Andhra Pradesh (Moses and Reddy, 1989).

Botrytis grey mold caused by *Botrytis ricini* Godfrey (Godfrey, 1923) is mostly confined to spikes/raceme. Under favourable conditions disease rapidly spreads to stems and leaves. Continuous wet weather, temperature about 30°C and relative humidity of 90% are highly conducive for the disease development. The spores from infected capsules are readily disseminated by the wind and splashing rainfall causing secondary infection. Once the inoculum establishes on the host plant the whole spike rots within 5-7 days leading to complete loss. Thus the management of the disease is difficult if not controlled at an early stage of disease incidence. Besides, genetic sources resistant to the disease are lacking and other remedial measures were not effective. However, morphological traits of castor that would assist the growth of the fungus were identified (Thomas and Orellane, 1964). Identification of host resistance is one of the viable options for disease management. Released hybrid varieties of castor available at Directorate of Oilseeds Research (DOR), Hyderabad were screened in field under natural conditions and results are presented in this paper.

Materials and methods

Eight castor cultivars (Table 2) were screened against Botrytis grey mold of castor under the field conditions at DOR, Hyderabad during July-September 2010. Each variety was sown in ten rows in a plot size of 25 m x 40 m with spacing of 90 cm x 60 cm. In each variety 30 plants were selected randomly and the per cent disease index was recorded in the primary, secondary and tertiary spikes. To study the influence of climatic conditions on the severity of disease incidence, various weather parameters *viz*., temperature, relative humidity, number of rainy days, rainfall prevailed during August -September 2010 were also recorded (Table 1).

Result and discussion

A total of eight castor varieties (Table 2) were screened for their reaction against *Botrytis* grey mold under natural conditions in field during July-September 2010. Grey mold incidence was observed during the 2nd week of August, 2010, when congenial weather conditions coincided with the capsule development stage of secondary spikes of castor. During this week the average temperature was 26.9°C and relative humidity was 95% with 5 continuous rainy days (rainfall- 73.6mm) (Table 1). The weather conditions prevailed till September 23 starting from 1st August (mean max. temp.29.4°C, mean RHI 90.6% and 23 rainy days) further helped disease development. These conditions were highly favourable for the development and spread of the disease (Raoof and Yasmeen, 2006). Among eight castor varieties, DCS-107 showed highest per cent disease index of 69.5 (Table 2). Tolerant variety of 48-1 showed lowest per cent disease index of 28.1 mainly due to the non-spinyness of capsules. Remaining all varieties/hybrids showed disease index more than 40%. The present study clearly showed the reaction of various cultivated varieties/hybrids reaction to the *Botrytis* grey mold.

Table 1 Weekly meteorological data recorded at Rajendranagar from August to September 2010

Meteorological week No.	Period	Temperature (oC)		Relative humidity (%)		Rainfall (mm)	Rainy days	Mean temperature (oC)
		Max.	Min.	RH-I	RH-II			
31	30-05 Aug	29.0	22.5	88	70	13.8	2	25.7
32	06-12	29.5	22.2	90	72	25.2	2	25.9
33	13-19	30.9	23.1	93	76	64.5	4	27.0
34	20-26	31.3	22.5	95	75	73.6	5	26.9
35	27-02 Sep	28.3	22.7	88	81	35.0	1	25.5
36	03-09	27.4	22.2	91	82	42.4	4	24.8
37	10-16	30.2	22.5	90	67	26.4	2	26.4
38	17-23	29.2	21.9	90	68	85.4	3	25.5
	Average	29.4	22.4	90.6	73.8	45.7	2.8	25.9

Table 2 Screening of castor cultivars resistance to *Botrytis* gray mold (*Botrytis ricini*)

Variety/hybrid	Per cent disease index (PDI)
DCH-519	50.3
GCH-4	42.3
GCH-7	41.7
DCH-177	40.7
Haritha	43.9
DCS-107	69.5
DCS-9	47.8
48-1	28.1

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Identification of castor germplasm accessions resistant to diseases and nematodes

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Abstract

A total of 115, 198 and 120 castor germplasm lines were screened against *Fusarium* wilt, *Macrophomina* root rot and reniform nematodes respectively during the years 2007, 2008 and 2009. Screening of germplasm accessions resulted in identification of few disease free and resistant lines. 115 germplasm lines were screened against *Fusarium* wilt at two locations, Hyderabad and S.K. Nagar to confirm the resistant reaction of the castor lines. Among these 115 germplasm accessions, 8 lines were identified as wilt free and 27 lines as resistant during the years 2007-09. Five lines *viz.*, RG-2809, 2819, 2818, 2822 and 3016 were found to be resistant to all the three diseases.

Keywords: *Fusarium* wilt, *Macrophomina* root rot, reniform nematode, germplasm, resistant sources

Introduction

Castor (*Ricinus communis* L.) production is greatly influenced by the biotic and abiotic stresses existing in the soil. In India, the most common fungal pathogens that affect the yield of castor include *Fusarium oxysporum* f.sp. *ricini* (wilt), *Macrophomina phaseolina* (root rot) and *Botrytis ricini* (grey mold). They continue to dominate the disease scenario in different agroclimatic regions and the disease incidence ranges from 35 to 67% (AICRP, 2009) Castor is also damaged by root knot nematodes present naturally in the soil. The interest in the study of pathogenic effect of nematode on castor has increased because it predisposes the infection of wilt pathogen *F. oxysporum* f.sp. *ricini* (Chattopadhyay and Reddy 1995; Chattopadhyay *et al.*, 1996). Castor was reported to be resistant to *Meloidogyne thamesi* and *Meloidogyne hapla* (Lear and Miyagawa, 1966). But the varieties screened were not resistant. Effective control measures are not reported for these diseases and identification of resistant cultivars will be a valuable approach for the control of these diseases. Thus, the present study was conducted to identify castor germplasm lines resistant to multidiseases at various locations.

Materials and methods

***Fusarium* wilt**: To identify the castor germplasms resistant to wilt, a total of 115 germplasm accessions were screened against *F. oxysporum* f.sp. *ricini* at the Directorate of Oilseeds Research (DOR), Hyderabad and S. K. Nagar, Gujarat during 2007-09. At DOR each accession was sown in a single row of 6m length (20 plants/row) in highly wilt-sick plots with susceptible check variety VP-1 or JI-35 and resistant check DCS 9 planted after every 5 test rows. At S.K. Nagar, each accession was sown in a single row of 6.75 m length (15 plants/row) with same susceptible and resistant varieties being planted after every 20 and 5 test rows respectively. The inoculum load in the wilt-sick plot was 2046-3023 CFU/g soil. Disease incidence was monitored periodically at 30-day intervals up to 150 days and 180 days at DOR and S.K. Nagar respectively.

***Macrophomina* root rot**: Screening against *Macrophomina* was carried out in a root-rot-sick plot at Junagadh Agricultural University. A total of 198 accessions were screened for 2 years along with the susceptible (GCH-4) and resistant (JI-363 or JI-357) checks after every five test rows. The debris of diseased plants was incorporated in the root-rot-sick plot and each plant was inoculated with 50 g fungal culture grown on sorghum grains. Disease incidence was recorded at 100,125 and 170 days after sowing.

Nematodes: A total of 120 accessions were screened against reniform nematodes at DOR, Hyderabad during 2007-09 under greenhouse conditions by artificial inoculation conditions. The disease incidence was recorded based on the number of females or egg masses present in the roots of the crop: using standard scale (0-highly resistant; 1-2.0, resistant; 2.1-4.0, moderately resistant, 4.1-6.0, susceptible and more than 6.1, highly susceptible).

Results and discussion

Major fungal diseases of castor greatly reduce the yield of the crop. Management trials conducted so far have not met with much success. Keeping this in mind, germplasm material available at DOR, Hyderabad were screened under artificial inoculation conditions during 2007-2009 to identify multiple disease resistant material at multilocations.

During the three consecutive years from 2007-09, a total of 115 castor germplasm lines were screened against *Fusarium* wilt at DOR and S. K. Nagar to identify the lines resistant to wilt. Wilt incidence ranged from 0-20% in resistant lines. Various wilt free and wilt resistant lines were identified (Table 1). Germplasm screening under root-rot-sick plot at the Junagadh centre led to identification of few sources of resistance to root rot (Table 2). The disease incidence ranged from 0-20% in the resistant lines. Similarly, resistant sources were identified for reniform nematode (Table 3).

Among the 115 accessions screened against wilt, 8 lines were wilt free and 27 lines were found to be resistant to *Fusarium* wilt at 2 locations (Table 4). A total of 115, 198 and 120 accessions were screened against wilt, root rot and nematodes during the years 2007-09; 11 lines showed resistant reaction towards wilt and root rot, 9 lines to wilt and nematode, 5 lines were resistant to root rot and nematodes and 5 *viz.*, RG-2809, 2819, 2818, 2822 and 3016 lines exhibited resistance to wilt, root rot and nematode (Table 5). The multidiseases and multilocation germplasm identified may be used in resistance breeding programmes for incorporating resistance to *Fusarium* wilt, *Macrophomina* root rot and reniform nematodes.

Table 1 Selection/identification of castor resistant lines for *Fusarium* wilt

Years of screening	Number of germplasm lines screened	Immune (0% Wilt)		Resistant lines (< 20% Wilt)	
		DOR	S. K. Nagar	DOR	S. K. Nagar
2007-2008	38	RG-2522, 2758, 2779, 2819, 2927, 3016	RG-2758, 2809, 2818, 2819, 2822, 2925, 2745, 2781, 2820	RG-2388, 2787, 2818, 2970	RG-2787, 3016, 2388, 2746, 2922, 3023, 2871, 2890, 81
2008-2009	38	RG-157, 404, 411, 631, 1631, 1638, 1686, 1926, 2284, 2388, 2606, 2891	RG-439, 650, 1929, 2746	RG-256, 340, 391, 650, 675, 1108, 1923, 1929, 2019, 2746	RG-404, 411, 430, 1631, 2151, 2388, 2606, 2891
2009-2010	40	RG-2271, 2800, 2787, 3016, 1624, 1954, 2810, 2822, 1337, 1241, 1350, 1628, 1607, 2695, 2694	RG-109, 1442, 1624, 2271, 2559, 2719, 2722, 2727, 2728, 2787, 2822, 3016	RG-1654, 2725, 2228, 1202, 2726, 2777, 109, 1354	RG-357, 1241, 1337, 1354, 1607, 1628, 1654, 1954, 2228, 2297,2582, 2694,2695, 2696,2717,2723,2725 2726, 2800, 2837

Table 2 Selection/identification of castor resistant lines for root rot in sick plot conditions

Years of screening	Number of germplasm Lines screened	Root rot free lines (0%)	Root rot resistant lines (< 20%)
2007-08	38	RG-2787, 2809, 2819, 2746, 2088	RG-2818, 2822, 2388, 3023, 2871, 2890, 2820
2008-09	-	-	-
2009-10	160	-	RG-3120 & RG-1834

Table 3 Selection/identification of castor resistant lines for reniform nematodes

Years of screening	Number of germplasm lines screened	Nematode resistant lines	
		Highly resistant lines (0 no. of females/egg mass/plant)	Resistant lines (1-2 no. of females/egg mass/plant)
2007-08	42	RG-2809, 2819,2781	RG-2779, 2818, 2822, 3016, 2816, 2695, 2726, 2767, 3041, 3048, 2829, 3018, 1628, 2241, 2270, 2271
2008-09	38	-	RG-157, 1628, 1654, 2719, 2732, 2752, 2765, 2800, 3048, 3126, 3139
2009-10	40	RG-2582	RG-2271, 2719, 2787, 2822, 3139

Table 4 Castor germplasm accessions resistant to *Fusarium* wilt at multilocations

Years of screening	Wilt free lines (0%)	Wilt resistant lines (< 20% infection)
2007-08	RG-2758, 2819	RG-3016, 2818, 2388, 2787
2008-09	-	RG-404, 411, 1631, 2388, 2606, 2891, 650, 1929, 2746
2009-10	RG-2271, 2787, 3016, 1624, 2822	RG-2800, 1954, 1337, 1241, 1628, 1607, 2695, 2694, 109, 1654, 2725, 2228, 2726, 1354

Table 5 List of castor germplasm accessions resistant to multidiseases (2007-09)

Fusarium wilt and *Macrophomina* root rot resistance	*Fusarium* wilt and nematode resistance	*Macrophomina* root rot and Nematode resistance	*Fusarium* wilt, *Macrophomina* root rot and Nematode resistance
RG-2746, 2822, 3023, 2871, 2787, 2818, 2819, 2809, 2388, 2890, 2820	RG-2809,2819, 2818, 2822, 3016, 2779, 2582, 2719, 2787	RG-2809,2819, 2818, 2822, 3016	RG-2809,2819, 2818, 2822, 3016

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Classification of castor entries based on some essential quality traits

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Abstract

Ninety two castor entries were re-examined for the important characteristics *viz.*, oil content, test weight (i.e. 100 seed weight) and ricinoleic acid (RA). Based on these characteristics entries were classified into low (<μ-1σ), medium (μ-1σ to μ+1σ) and high (>μ+1σ) categories where μ and σ was mean and standard deviation, respectively. Oil content among the castor entries varied from 22.3 to 52.9%. Test weight ranged from 16.5 to 43.8 g and RA varied from 70.7 to 92.3%. Mean and standard deviation values for oil content were 45.4% and 8.8, for test weight 29.8 g and 5.1 and for RA, 87.0% and 2.4, respectively. In low oil content (i.e., < 36.5) there were 16 entries, while the rest was in medium category. Ricinoleic acid content was low (i.e., < 84.5%) in four castor entries and in eight entries its content was high (i.e.,> 89.4%).

Keywords: Castor entries, oil content, ricinoleic acid

Introduction

Castor has the potential to become the premier vegetable oil crop for industrial oil production across the globe (Roetheli *et al.*, 1991). Castor is an ideal contender for production of high value, industrial oil feed-stocks because of the very high oil content (48-60%) of the seed, the extremely high levels of potential oil production (500- 1,000 l of oil/acre) and the plants unique ability to produce oils with extremely high levels (80-90%) of ricinoleic acid (12-hydroxyoctadeccis-9-enoic acid) (Brigham, 1993). Additionally, the high potential yield and unique fatty acid composition of castor allow this oil to provide economically competitive feed-stocks required for the production of premium quality biodiesel, short chain aviation fuels, fuel lubrication additives, and very high value biopolymers (Geller and Goodrum 2004; Goodrum and Geller 2005; Roetheli et al., 1991). Because castor is non-edible and can be grown productively on marginal lands this crop represents a unique opportunity to expand industrial vegetable oil production on a global basis. In India, during the year 2008-09 castor was cultivated in 866.2 thousand ha with an economic produce of 1171.2 thousand t. Average productivity of the crop was 1352 kg/ha, which was higher than the world average, i.e., 1037 kg/ha. Assuming that the average oil content in the seed is 48 to 51% the total oil yield varied from 649 to 689.5 kg.

Castor entries vary in their quality traits among which oil content, test weight and ricinoleic acid (RA) are very important as the castor research workers strive to improve these characteristics in the newly advanced varieties and hybrids. In this paper, an attempt has been made to classify some of the castor entries into low, medium and high categories with respect to these quality traits. The information generated may be useful to the castor breeders in fine tuning the breeding programmes related to the most important quality traits.

Materials and methods

In the present investigation, 92 castor entries were reviewed for the most important characteristics *viz.*, oil content, test weight (i.e., 100 seed weight) and RA. Data pertain to these traits was taken from the published literature (Bhardwaj *et al.*, 1996; DOR, 2008; 2009 and 2010). Based on the characteristics studied castor entries were classified into low (<μ-1σ), medium (μ-1σ to μ+1σ) and high (>μ+1σ) categories where μ and σ was mean and standard deviation respectively (Sarkar and Deb, 1984).

Results and discussion

In this study, oil content among the castor entries varied from 22.3 to 52.9%. Test weight ranged from 16.5 to 43.8 g and RA varied from 70.7 to 92.3%. Mean and standard deviation values for oil content were 45.4% and 8.8, for test weight 29.8 g and 5.1 and for RA, 87.0% and 2.4, respectively. It was observed that most of the castor entries were under the medium category with respect to the characters studied (Table 1). In the present investigation, under high oil content (i.e., ≥ 54.2) category not even a single castor entry was found. However, under low oil content (i.e., ≤ 36.5) there were 16 entries while the rest was in medium category. Few entries placed under the low oil content category have relatively high RA and test weight. Achieving nearly 56% oil content in castor varieties and hybrids under Indian conditions is currently, a daunting task for the researchers. In general, castor entries with low test weight are not preferred by farmers and traders as they contain low oil content and also fetch a low market price. Test weight of the castor entries, showed that there were 13 in low (i.e., ≤ 24.7) and 10 in high (i.e., ≥ 34.9) and rest was in medium category.

Ricinoleic acid content was low (i.e., ≥ 84.5%) in four castor entries, while in eight entries it was high (i.e., > 89.4%) the rest was classified to medium category (Table 1). Variation in RA content (86-90%), in improved castor genotypes has been reported earlier (Nagaraj and Srinivas, 2001). Attempts to obtain >90% RA is the challenge before the castor researchers because of its multipurpose uses. Low RA entries can be used for reducing the content further low to exploit them for food and other industrial purposes.

Present study, clearly showed the limitations in the important quality traits in some of the currently cultivated species, as majority of them is under the medium category. Breeding programmes in castor are mostly aimed to achieve high oil content, test weight and RA. A detailed analysis of the available castor germplasm for all the important traits is essential to identify much more improved and potential castor genotypes for various industrial and other applications. Of late efforts to develop low RA and high oleic acid castor genotypes for edible and various other industrial applications requiring high oxidative stability, such as for biofuel, or pharmaceutical applications requiring lower ricinoleic levels than the standard castor oil (Rojas Barros, 2004) were in progress. The question of how the castor seed produces oil with such a high proportion of ricinoleate and high oil content, nearly approaching 60% continues to provide a challenge. Understanding this process by castor researchers may eventually lead to increased oil content and the ability to engineer the production of other uncommon and industrially useful fatty acids in the castor seed.

Table 1 Classification of castor entries for some quality traits

Character	Low (<μ-1σ)	Medium (μ-1σ to μ+1σ)	High (>μ+1σ)
Seed oil content (%)	PI248950, PI248945, PI248947, PI254406, PI254405, PI248393, PI248967, PI202668, PI248939, PI248970, PI248391, PI248941; PI248946, PI248390, PI248943, PI248392	48-1, DCH-177, DCH-519, DCS-105, DCS-106, DCS-107,DCS-9, DSP-222, GC-2,GC-3, GCH-4,GCH-5,GCH-6, GCH-7,Geeta, JC-1, JC-2, JHB-958, MCI-2, MCI-3, RHC-199, SHB-824, SHB-864, SKI-215, SKI-307, SKP-84, VP-1, DC-105, DCS-108, GAUC-1, GAUCH-1, GCH-2, GHC-6, JC-10, JC-12, JC-8, JHB-968, JHB-969, JI-342, JI-35, JI-353, JI-368, JI-96, JP-65, JP-96, MCI-10, MCI-5, MCI-8, MCI-9, NBCH-11662, NBCH-2007-1, NBCH-2007-2, PCH-234, PCH-244, PSC-1111, RHC-270, RHC-277, SAGAR SIDHI, SH-72, SHB-834, SHB-846, SHB-849, SHB-872, SHB-873, SKI-294, SKI-304, SKI-332,SKI-338, SKP-106, SKP-113, SKP-114, SKP-23, SKP-42, SKP-72	---
100 seed weight (g)	DCS-108, GAUC-1, GCH-2, MCI-5, MCI-8, SKP-113, SKP-114, P1248950, P1248947, P182987, P1202668, P1202667, P1248970	48-1, DCH-177, DCH-519, DCS-105, DCS-106, DCS-107,DCS-9, DSP-222, GC-2,GC-3, GCH-4,GCH-5,GCH-6, GCH-7,Geeta, JC-1, JC-2, JHB-958, MCI-3, RHC-199, SHB-824, SHB-864, SKI-215, SKI-307, SKP-84, VP-1, DC-105, GAUCH-1, GHC-6, JC-10,JC-8, JHB-969, JI-342, JI-35, JI-353, JI-368, JI-96, MCI-10, NBCH-11662, NBCH-2007-1, NBCH-2007-2, PCH-234, PCH-244, PSC-1111, RHC-270, RHC-277, SAGAR SIDHI, SH-72, SHB-834, SHB-846, SHB-849, SHB-872, SHB-873, SKI-294, SKI-304, SKI-332,SKI-338, SKP-106, SKP-23, SKP-42, SKP-72, P1248945, PI248393, PI248967, PI248939, PI248970, PI248941,PI248946, PI248943, PI248392	MCI-2, JC-12, JHB-968, JP-65, JP-96, MCI-9, P1254406, P1254405, P1248391,P1248390
Ricinoleic acid (%)	GAUCH-1, P1248396, P1248970, P1248391	48-1, DCH-177, DCH-519, DCS-105, DCS-106, DCS-107,DCS-9, DSP-222,GC-2,GC-3, GCH-4,GCH-5,GCH-6, GCH-7,Geeta, JC-1, JC-2, JHB-958,MCI-2, MCI-3, RHC-199, SHB-824, SHB-864, SKI-215, SKI-307, SKP-84,VP-1, DC-105, DCS-108, GAUC-1, GCH-2, GHC-6, JC-10, JC-12, JC-8, JHB-968, JHB-969,JI-342, JI-35, JI-353, JI-368, JI-96,JP-65, JP-96, MCI-10, MCI-8, MCI-9, NBCH-11662, PCH-234, PCH-244, PSC-1111, RHC-277, SH-72, SHB-834, SHB-846, SHB-849, SHB-872, SHB-873, SKI-294, SKI-304, SKI-332, SKI-338, SKP-106, SKP-113, SKP-114, SKP-23, SKP-42, SKP-72, PI248950, PI248947, PI254405, PI248393, PI202668, PI248939, PI248941, PI248946, PI248390, PI248943, PI248392	MCI-5, NBCH-2007-1, NBCH-2007-2, RHC-270, SAGAR SIDHI, P1248945, P1254406, P1248967.

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Protein isolation from defatted castor cake

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Abstract

An analytical process to produce a protein isolates from defatted castor cake was developed by modifying a method originally developed for rape-seed. The optimized process consisted of extraction at pH 11, ultrafiltration with concentration factor 4, filtration with Whatman filter paper, and precipitation at pH 5. By this process, 10.1-18.3% of the precipitated protein isolates, 22-41.6% soluble protein and unrecoverable products and 46.6-65.6% meal residue were recorded in the defatted seed cake of various castor genotypes. The work confirms that castor is a potentially useful source of adhesives and plastic making products.

Keywords: Castor cake, protein isolates, ultrafiltration

Introduction

The castor seed contains 15-30% protein while the defatted castor cake contains 20-30% crude protein. The protein cannot be used for animal and human food because it contains ricin, which is poisonous if inhaled, injected or ingested. Castor cake contains many amino acids like, lysine, arginine, aspartic acid, serine, tyrosine, glycine, alanine, glutamic acid, etc. Several methods were developed for the production of protein isolates and concentrates from the oilseed crops. Procedures that produce isolates generally involve oil extraction, solubilization of protein, purification, precipitation and drying. Tzeng *et al.* (1990) used canola seed to successfully develop a process that produces three products: an isoelectric protein, a soluble protein isolates, and a meal residue. To develop a viable protein recovery process, the work involves determination of the influence of pH on protein extractability and precipitation. From the results, optimal pH values were chosen for the extraction and precipitation stages, and the appropriate concentration factor for ultrafiltration and filtration were defined.

Materials and methods

Seeds of 18 castor genotypes (Table 1) were used for the protein isolation investigation. Initially, the seed was ground and defatted with petroleum ether, using the soxhlet apparatus, for 24 hr and then dried overnight in an oven. Oil content, crude protein and moisture contents in the seeds of studied castor genotypes were found to be 45-50%, 15-30% and 7-12%, respectively. The defatted castor cake obtained from the respective castor genotypes was subjected to the protein isolation process as described below.

The protein extractability was determined by contacting 10 g castor cake with water (ratio 1:18) then the pH was adjusted to 11.0 using 25% NaOH and held at this pH for 30 min. The extraction and solid were separated by centrifugation at 12000 rpm. The liquid was collected and the solids were then washed twice with double distill water. All the solution was collected into the same receiving flask. Then the washed solids were frozen dried to produce meal residue .Extracted solution was adjusted to pH 10.5 with 0.05M NaOH and heated to 50-60°C for 30 min. The heat treated extract is concentrated by using ultrafiltration membrane at 4 concentration factor, and then filtered with Whatman filter paper. The extract was adjusted to pH at 5.0 using 5 M H_3PO_4. Again the extract and solids were separated by centrifugation at 12000 rpm. The liquid portion was again ultra-filtered and purified. Retentate was frozen dried to obtain soluble protein. The solid portions obtained at this stage was washed with double distill water for two times and frozen dried to obtain the precipitated protein isolate (Rebecca Marnoch and Diosady, 2006).

Table 1 Protein, meal residue and soluble protein and unrecoverable products in the defatted cake of various castor genotypes

Castor genotype	Protein (%)	Meal residue (%)	Soluble protein and unrecoverable products (%)
GCH-7	18.2	52.7	29.1
GCH-5	14.3	56.9	28.8
GCH-4	11.9	46.6	41.6
VP-1	12.7	56.5	30.8
JI-96	18.0	53.0	29.0
48-1	12.5	65.6	22.0
SKI-215	17.0	55.7	27.3
Geeta	12.7	63.5	23.8
SKP-84	10.1	61.5	28.4
GCH-6	13.9	62.3	23.8
SH-72	11.0	60.9	28.1
GAUCH-1	12.5	62.3	25.2
JI-35	13.8	47.8	38.4
JP-65	18.3	55.6	26.2
GCH-2	11.4	63.2	25.4
GC-2	14.7	60.6	24.7
VI-9	11.2	59.8	28.9
GCH-3	16.0	56.2	27.8

Results and discussion

The protein content in the seed cake portion of castor genotypes was in the range of 10.1% (SKP-84) to 18.3% (JP-65). Among all the genotypes, JP-65 (18.3%) recorded maximum protein content followed by GCH-7 (18.2%) (Table 1).

As demonstrated, a modified protein isolation procedure was successfully developed using defatted ground castor seed as the starting material. The total crude protein recovery in the three products streams were, solid protein (10.1 to 18.3%), meal residue (46.6 to 65.6%) and other soluble protein and unrecoverable products (22.0 to 41.6%). The taste of this product was bland, and the colour was slightly black. The solid protein can be used in the adhesives and plastic making products industry.

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Productivity improvement in castor through frontline demonstrations

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Abstract

Castor is an important industrial oil seed crop of dryland areas in India. Castor oil accounts to be a raw material for various pharmaceutical, cosmetic and lubricant industries. Frontline demonstrations (FLDs) were conducted through technological interventions on castor during the period from 2006 to 2009 under rainfed conditions. The whole package and component technology in hybrid castor showed that seed cultivation of hybrid castor instead of varieties and traditional land races, improved the yield upto 45%. Adoption of whole package practices improved the yield upto 70% and adoption of plant protection technology improved the yield upto 50%.

Key words: Castor, whole package demonstrations

Introduction

Castor hybrid is a newly introduced and commercially exploited crop in India. The crop has been playing an important role in national economy by earning foreign exchange of Rs. 2000 crores/annum through export of castor oil. At present, castor covers an area of nearly 8.1 lakh ha with a production of 11.1 lakh t in the country (AICRP Castor Report, 2010). Gujarat, Rajasthan, Karnataka and Tamil Nadu are the main castor producing states in India. In Tamil Nadu, Salem and Namakkal are the leading districts in cultivation of castor followed by Erode. Many technologies for castor cultivation have been evolved for increasing productivity but farmers have not adopted many of them. An attempt was made to identify the production constraints/gaps in cultivation of castor through participatory rural appraisal in adopted villages and presented in the paper. The speedy adoption of improved agricultural technologies and innovations is most important for enhancing agricultural production at faster rate and hence it is a crucial aspect under innovation diffusion process. The main objective was to demonstrate the productivity potential and profitability of the latest improved production technologies under real farm situations.

Materials and methods

The productivity potentials and profitability of the latest improved castor technologies were demonstrated under farmers' field conditions at 145 locations in adopted villages of Tapioca and Castor Research Station, Yethapur under rainfed conditions. Scientists adopted the villages *viz.*, Elachipalayam, Namagiripettai, Vaiipanmalai, Thengalpalayam, Pethanaickenpalayam and Chennampatti of Nammakkal, Salem and Erode districts of Tamil Nadu. Different extension activities were taken up for technology assessment. The beneficiary farmers were identified based on the proportionate random sampling method. The cause for low yields of castor were identified and then prioritized. Based on the major causes and constraints for low yields, i.e., poor package of practices, non-adoption of hybrid seeds and plant protection measures, non-availability of labourer during the critical crop growth period, the technological interventions were initiated during the year 2006-2007 and continued upto 2009-2010 crop season through whole package demonstration and component technology demonstrations. One pre-season orientation training was conducted to the selected farmers and regular field visits were made to explain the production technology of castor particularly on hybrids and plant protection measures. Sowings were done in red soils at spacing of 90 cm x 60 cm during II fortnight of June in all the years of demonstrations. Each demonstration plot both with improved technology (IT) and farmers' practice (FP) had an area of 0.4 ha. Whole package technology, improved castor hybrids (DCH-519 and YRCH-1) and plant protection measures were the technologies demonstrated. The production potential of improved technologies were worked out taking the mean yields attained through demonstrations. The economics of improved technology in relation to prevailing farmers' practices was studied to know the profitability of the technology. The superiority of IT over FP was assessed mainly in terms of yield increase, additional net returns and benefit cost ratio.

Results and discussion

The data generated through the frontline demonstrations conducted during the period had shown the potential of various improved technologies in castor (Table 1). Yield, net returns and benefit cost ratio was more when whole package was adopted.

Whole package: The increase in yield in whole package was due to introduction of hybrids, controlling of weeds at early stages by herbicidal application combined with one hand weeding on 20 DAS and controlling of pest and disease by taking need based plant protection measures. The mean seed yield increase of whole package technologies over the farmers' practices was 73% with a B:C ratio of 3.5.

The mean seed yield increase of improved cultivars (DCH-517 and YRCH-1) over the farmers' practice (TMV 2) was 54%. Frontline demonstrations conducted on castor indicated that the per cent increase in seed yield ranged from 50 to 70% over the farmers' practice. Castor yield was more in improved technologies due to supply of certified foundation seeds from the Tapioca and Castor Research Station, Yethapur. Instead of using the variety, farmers were advised to cultivate the hybrid recommended for their region along with weed control measures at early stages and adopting need-based plant protection measures to double the yield in rainfed castor and also to enhance profit obtained by castor growing farmers.

Table 1 Productivity improvement in castor through technological interventions

Intervention	Demonstrations (ha)	Year	Mean seed yield (kg/ha)	Increase in yield (%)	B:C ratio
Whole package	15	2006	970	72	3.8
Hybrid castor	15	2006	860	48	3.1
Whole package	15	2007	1020	68	3.5
Hybrid castor	15	2007	936	49	3.0
Whole package	30	2008	1013	77	3.7
Hybrid castor	10	2008	925	58	3.2
Whole package	35	2009	844	75	3.0
Hybrid castor	10	2009	819	62	3.0

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Assessment of improved castor production technologies under real farm situations

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Abstract

To demonstrate the productivity potentials and profitability of improved production technology, frontline demonstrations were conducted at farmer's field with improved production technology and farmer's practice. The impact study revealed that the frontline demonstrations improved the yield and monetary returns with adoption of improved castor production technology. The mean seed yield increase of improved technology was 39.5% with mean additional net returns of ₹ 7815/ha.

Keywords: Frontline demonstrations, castor, impact, improved technology

Introduction

Castor (*Ricinus communis* L.) is a non-edible oilseed crop and plays an important role in Indian economy. India dominates world castor production and its share in world's area and production of castor is 68% and 76%, respectively (Reddy *et al.*, 2006). India is self-sufficient in food grains, but production of oilseed crops remains static since last 40 years (Patel *et al.*, 2009). To accelerate the production of oilseeds, Department of Agriculture and Cooperation (DAC) started FLD programme. Agro-climatic conditions of Uttar Pradesh is quite suitable for castor cultivation but it is cultivated on a very limited scale due to lack of improved production and protection technologies (Srivastava, 2007). With a view to convince the farmers about the productivity potentials profitability of improved production technology, these demonstrations were carried out at farmer's fields.

Materials and methods

Frontline demonstrations on castor were conducted during the period 2006-07, 2007-08, 2008-09 and 2009-10 to show the productivity potentials of whole package technology on castor crop *vis-à-vis* prevailing farmers practices at farmer's fields in different regions of U.P. under rainfed situations.

Results and discussion

In all the years, mean seed, yield of improved technology was higher as compared to farmer's practices, which was due to timely sowing of crop with recommended hybrids/varieties and fertilizer management. The data indicated that the castor seed yield under improved technologies ranged from 1802 to 1933 kg/ha with the mean of 1874 kg/ha against the seed yield ranged from 1300 to 1391 kg/ha with a mean of 1343 kg/ha recorded under farmer's practices (Table 1). In comparison to farmer's practices, there was an increase in IT yield ranging from 39 to 40% with a mean of 39.5%. Santosh, *et al.* (2007) also recorded the yield improvement in castor with improved technology over traditional practices ranged from 150-250 kg/ha under sole crop. Vaghasia and Kavani (2009) reported from Gujarat that the yield enhancement under improved technology ranged from 14 to 28% and by and large, in all the years, yield of demonstration plot was higher as compared to local check.

Table 1 Productivity potentials of improved technologies in castor during 2006-07 to 2009-10

Year	Hybrid/ varieties	No. of FLDs	Area (ha)	Average yield (kg/ha)		Increase in yield (%)
				IT	FP	
2006-07	DCH-177	10	4.0	1802	1300	39
2007-08	GCH-4	10	4.0	1838	1310	40
2008-09	GCH-4	15	6.0	1924	1372	40
2009-10	48-1	15	6.0	1933	1391	39
Mean	-	-	-	1874	1343	39.5

It was found that the production cost of improved technology was a little higher than the farmer's practice in all the years. The production cost of castor varied form ₹ 5769 to ₹16310/ha with an average of ₹12987/ha for improved technology plot against the variation in cost of production form ₹ 3375 to ₹13605/ha with an average of ₹ 10136/ha in farmer's practices (Table 2). Cultivation of castor with improved technology gave higher net returns ranged from ₹ 22285 to ₹ 28308/ha with a mean value of ₹ 24790/ha as compared to farmer's practices which ranged from ₹ 17303 to ₹ 18383/ha with a mean value of ₹ 17021/ha. The improved production technology registered an additional net returns ranging from ₹ 4982 to ₹ 9925/ha with a mean of ₹ 7815/ha over farmer's practices. According to Padmaiah (2007) the adoption of improved hybrids (DCH-32 and DCH-177) resulted in higher yields and returns under similar input management conditions. Vaghasia and Kavani (2009) noted 22% increase in net returns with adoption of improved technology. It can be concluded that the cultivation of castor with improved production technology proved more productive and remunerative than that grown with local practices.

Table 2 Profitability of improved technologies (₹/ha)

Particulars	Years				Mean
	2006-07	2007-08	2008-09	2009-10	
Production cost					
Improved technology (IT)	5769	14350	15518	16310	12987
Farmer's practice (FP)	3375	10350	13215	13605	10136
Gross returns (₹/ha)					
Improved technology	28054	38041	40635	44618	37777
Farmer's practice	20678	27141	28878	31988	27157
Net returns (₹/ha)					
Improved technology	22285	23691	24875	28308	24790
Farmer's practice	17303	16791	15607	18383	17021
Additional net returns (₹/ha)	4982	6900	9454	9925	7815

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Information kiosk for knowledge dissemination in castor

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Abstract

India is passing through a challenging time as far as information technology is concerned. The Indian farmer urgently requires timely and reliable sources of information inputs for decision-making. The changing environment faced by Indian farmers makes information not merely useful, but necessary to remain competitive. Consequently, deploying information technology as a strategic tool for the benefit of rural India has assumed importance. Working towards this direction, it is felt necessary to have user-friendly systems particularly in local languages to create interest among the farmers. Information kiosk is one such a tool, which can educate the farmers about improved production technology of different forms and components of agriculture. Hence, it has been planned to dessminate the improved castor production technologies to castor growers and extension personnel through information kiosk. The information pertaining to castor varieties, hybrids, cultivation practices, production technologies, protection practices, disease management techniques, market intelligence etc., are converted into electronic format and are being made available to castor growers, extension workers, etc., through touch screen technology.

Keywords: Information kiosk, touch screen, improved castor production techniques

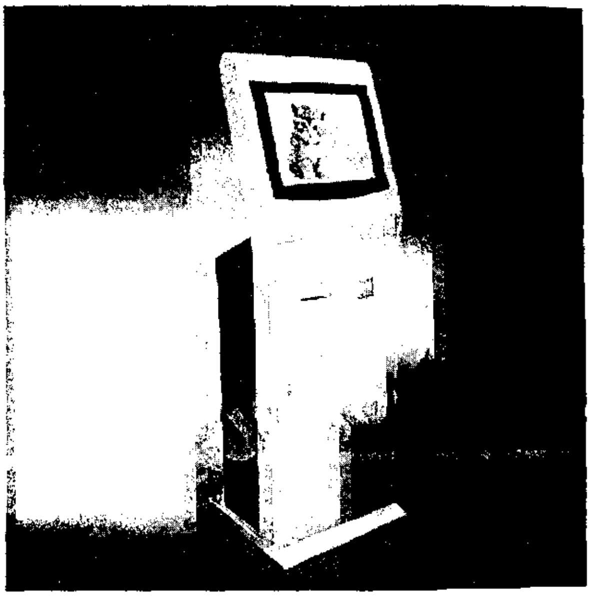
Introduction

Modern communication technologies when applied to conditions in rural areas can help improve communication, increase participation, disseminate information and share knowledge and skills. Improved communication and information access is directly related to social and economic development (Reddy and Ankaiah, 2005). The challenge is not only to improve the accessibility of communication technology to the rural population but also to improve the relevance of information to local conditions.

Millions of people desperately need access to updated technologies, improved varieties, better crop management and post-harvest techniques. Farmers need information about agriculture as a business, about the systems and sub-systems including administration, initiatives of other farmers, market information etc. While the existing extension system is unable to provide adequate information effectively and extensively to the farmers, the Information and Communication Technology (ICT) provides the flexibility in providing information on various mode of farming practices including the crops, commodities and enterprises (Chattopadhyaya and Das, 2004). ICT has proven to be effective alternative and comfortable in providing needed information of varying nature appropriate to the different farming environment systems/situations.

Materials and methods

The information needs of the extension personnel were assessed. Information related to market, improved varieties and hybrids, integrated nutrient management, integrated pest management, seed treatment and seed conditioning, harvest and post harvest techniques were the information needs of the extension workers with respect to the castor crop ranked in descending order of importance. Taking into consideration the information needs, an information system for castor was developed which caters to the needs of extension personnel, farmers, etc. The tool used to disseminate the information developed to various end users is information kiosk.



The information kiosk has a computer terminal that uses custom software designed to function flawlessly while preventing the users from accessing system functions. These kiosks can store data locally or retrieve it from a computer network. Integration of technology allows kiosk to perform a wide range of functions, evolving into self service kiosk.

Requirements

Hardware : Interactive kiosk come in many shapes and sizes and are often custom built for a specific application (Priyanka Vij, Harsh Chaudhary and Priyatosh Kashyap, 2010). A kiosk is configured with (i) a cabinet, (ii) CPU, (iii) display, (iv) peripherals and (v) additional signage area. The central processing unit (CPU) is the computer that runs the kiosk application. In many cases, it is a simple computer brought from a major manufacturer, which contains the processor, random access memory (RAM), hard disk and other components of a general PC. The display presents the kiosk application to the user. This display is simply a computer monitor, television or even flat-panel screen connected to the CPU.

Software : There are three categories of software that runs interactive kiosk which are (a) Operating system software (b) Application software and (c) Management software. Operating system software is loaded within the computer. Application software is custom made software which is developed to meet the information needs of the user which has many input screens, images, video clips, graphics, buttons, icons etc. Management software is used to handle the security tasks of the kiosk. Major advantages of using information kiosk are as follows:

Ensures round the clock service : Kiosk being machine-based intelligence system, it nullifies the need for human presence during its operation.

Encourages self-service : Kiosks are provided with custom built application software by means of which, the user can retrieve the information of his choice by himself as and when he needs

Easy maintenance : They are easy to maintain.

Limits functionalities and enhances focus : With limited interactions users are focused to the part of information for which they are interested.

Reduces work load : The application software developed for kiosk are custom made to meet the needs of the users, because of this the need of the personnel is reduced drastically.

Results and discussions

The information kiosk has been proposed to be exploded with the information that are prioritized based on the information needs of the castor growers and extension personnel who work for the development of castor. As far as the production technologies are concerned, the information will cover the following aspects:

i) Improved castor cultivars

ii) Planting techniques

iii) Integrated nutrient management

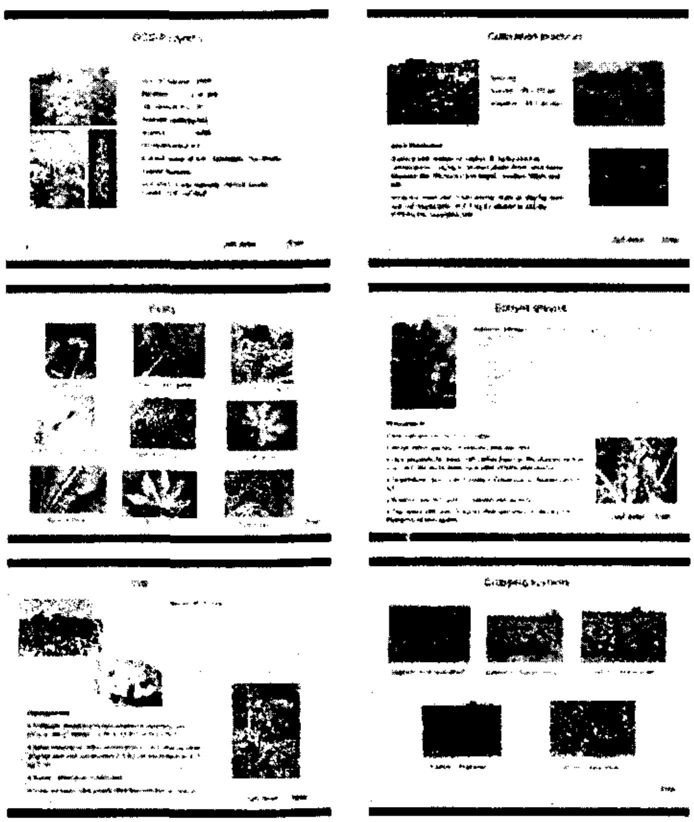
iv) Integrated pest management

v) Intercultural operations

vi) Irrigation/soil moisture management

vii) Harvest and post-harvest techniques

In addition to such information, it has been envisaged to link the system with websites of market information providers, short, and long range weather forecasting organizations, castor-related development departments, credit institutes, news, etc., to help the castor growers and the other stakeholders can have complete access to the holistic information domain of castor production. The information kiosk makes use of the knowledge from various sources and provides the oilseed grower with the desired solutions considering the various input parameters given by the user. Using this kiosk, it would be possible for the castor farmer to visually request the information from the database, access the information and make appropriate decision in the process of production of castor. By means of this information kiosk the interaction between the farmers and field experts will be increased.



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Impact of castor frontline demonstrations (FLDs) in Tamil Nadu

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Abstract

A study was conducted during February, 2010 to assess the impact of castor FLDs conducted by AICRP (Castor) centre at Yethapur, Tamil Nadu. The study was conducted on a comparative basis between FLD (74) and non-FLD (83) respondents randomly selected from Salem, Namakkal and Erode districts of Tamil Nadu. Analysis of the data collected revealed that there was significant difference between FLD and non-FLD farmers with respect to their adoption behaviour towards improved castor production technology. There was significant difference among small, medium and large non-FLD farmers with respect to their adoption behaviour. There was also significant difference among small, medium and large FLD as well as non-FLD farmers with respect to castor productivity. Farm size, experience with different castor cultivars and number of crops grown had significantly and positively influenced the adoption behaviour and the castor productivity of castor growers at 5% level of probability, whereas number of castor training programmes attended by the respondents had significantly and positively influenced at 1% level of probability. The perceived castor production constraints and suggestions to improve the castor production scenario in the study area were delineated.

Keywords: *Impact, FLDs, castor, Tamil Nadu*

Introduction

Castor (*Ricinnus communis* L.) occupies an important place in the country's vegetable oil economy. Presently, castor is grown over an area of 8.7 lakh hectares with a production of 11.7 lakh tonnes and productivity of 1352 kg/ha in the country (Anonymous, 2008-09). Despite the phenomenal increase witnessed in the production and productivity of castor over the last three decades, there still exists wide gap in the per hectare yields of castor across states. Further, the productivity potentials of the currently available improved castor production technologies which could be exploited under real farm conditions are considerably higher than the corresponding state or district average yields in all castor growing regions (Venkattakumar and Hegde, 2009). Bridging this wide commercially exploitable yield reservoir needs strengthening of extension efforts for taking the technologies to the farming community. All India Coordinated Research Project (AICRP) centres on Castor not only involved in developing location-specific castor production technologies but also in dissemination of such technologies through FLDs. Tapioca and Castor research Station at Yethapur, Tamil Nadu is one of such centres that regularly organizes FLDs under real farm conditions. Organizing FLDs on improved castor production technologies is one of the prime modes of transfer of technologies that have been utilized in dissemination of improved technologies. The impact of such FLDs on improving the level of adoption of improved castor production technologies of the farmers, the perceived production constraints in adopting improved technologies, felt training needs etc are to be assessed, so that other modes of extension efforts can be planned accordingly to popularize the technologies among the castor growers. Hence, a study was conducted to assess the impact of FLDs conducted by Tapioca and Castor Research Station at Yethapur, Tamil Nadu with the following objectives:

- To study the adoption behavior of castor growers towards improved castor production technologies
- To assess the production potentials and profitability of improved castor production technologies and
- To delineate the production constraints as perceived by the farmers and to suggest the strategies to improve the adoption behavior of farmers for higher yields and returns.

Materials and methods

An ex-post-facto impact study was conducted in Salem, Namakkal and Erode districts of Tamil Nadu during February, 2010. The impact assessment was done on a comparative basis between FLD (74) farmers and non-FLD (83) farmers selected based on simple random sampling procedure. Information pertaining to the demographic variables of the respondents; their adoption behaviour towards improved castor production technology, cost of castor cultivation and resultant castor productivity, perceived production constraints and training needs of the respondents based on their overall experience were collected through personal interview method in a structured data collection tool. The adoption behaviour of the respondents was measured by assigning unit score towards adoption of each recommended technology. Mean and standard deviation (SD) measures were used to assess the level of adoption behaviour and sunflower productivity. Significance of difference between FLD and non-FLD farmers with respect to their adoption behaviour and castor productivity was assessed through Mann-Whitney U (M-W U) test. Kruskal Wallis (K-W) test was used to find out the significance of difference between three categories of FLD and non-FLD farmers with respect to their adoption behaviour. Rank based quotient (RBQ) analysis (Shenoy *et al.*, 2006) was used to ascertain and prioritize the perceived production constraints and training needs of the respondents.

Results and discussion

Mann-Whitney U test revealed that there was significant difference between FLD and non-FLD farmers with respect to their adoption behaviour towards improved castor production technology (Table 1). Frequent contact of FLD farmers with researchers and development departmental officials and specialized on-campus and on-farm training on castor production technology received by the FLD farmers during the conduct of demonstration, might be the reasons for such results. The results of K-W test indicated that majority of the FLD and non-FLD farmers had small to medium size of land holdings (Table 2). There was no observed difference among small, medium and large FLD farmers with respect to their adoption behaviour. However, there was significant difference among small, medium and large non-FLD farmers with respect to their adoption behaviour. Difference among the three categories of farmers in awareness and lack of conviction towards the recommended castor production technologies might have brought such results. Distribution of castor growers based on respective castor productivity was assessed through K-W test and it was found that there was significant difference among small, medium and large FLD as well as non-FLD farmers with respect to the castor productivity experienced by them (Table 3). Difference among the three categories of farmers in both FLD and non-FLD in awareness and knowledge towards the recommended castor production technologies might have brought such results.

Correlation analysis revealed that the independent variables farm size, experience with different castor cultivars and number of crops grown had significantly and positively influenced the adoption behaviour and the castor productivity of castor growers at 5% level of probability, whereas number of castor training programmes attended by the respondents had significantly and positively influenced at 1% level of probability. It could be implied from the above results that castor growers with large farm size, having experience with many castor cultivars and undergone more training programmes may be utilized as FLD farmers and resource persons in training programmes for the castor growers to influence their adoption behaviour towards improved castor production technologies. RBQ analysis implied that damage due to *Botrytis*, severe incidence of insect-pests, non-availability of seeds of improved cultivars, non-availability and high cost of labours, fluctuations in market price, lack of awareness about the production technology, lack of ground water, poor soil and water conservation measures and problem due to poor electricity supply were the perceived production constraints ranked in the same order. Development of cultivars resistance to *Botrytis* disease and insect pests, with short structure and good branching nature, production and supply of quality seeds of improved cultivars, introduction of suitable intercropping system for higher returns and development and popularization of micro-irrigation system in castor were the suggestions as perceived by the castor growers to improve the castor production scenario in the study area.

Conclusions

There was significant difference between FLD and non-FLD farmers with respect to their adoption behaviour towards improved castor production technology. There was significant difference among small, medium and large non-FLD farmers with respect to their adoption behaviour. There was also significant difference among small, medium and large FLD as well as non-FLD farmers with respect to the castor productivity. Extension efforts need to be strengthened to improve the adoption behaviour of small, medium and large non-FLD castor growers and the productivity of castor experienced by both FLD and non-FLD farmers. Castor growers with large farm size, having experience with many castor cultivars and undergone more training programmes may be utilized as FLD farmers and resource persons in training programmes for the castor growers to influence their adoption behaviour towards improved castor production technologies.

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Table 1 Adoption behaviour of castor growers

Type of farmers	Number of farmers	Percentage	Z Value
FLD	74	47.13	2.832**
Non-FLD	83	52.87	

Mann Whitney U value = 2286.00; **=Significant at 1% level of significance

Table 2 Distribution of respondents according to their adoption behaviour

Type of farmers	Category of farmers	Number of farmers	Percentage	K-W value
FLD	Small (<2ha)	27	17.2	0.22NS
	Medium (2-5ha)	38	24.2	
	Large (>5ha)	9	5.73	
	Total	74	47.13	
Non-FLD	Small (<2ha)	37	23.57	6.56**
	Medium (2-5ha)	43	27.39	
	Large (>5ha)	3	1.91	
	Total	74	47.13	

NS = Non-significant; ** = Significant at 1% level of significance

Table 3 Distribution of castor growers based on productivity

Type of farmers	Category of farmers	Number of farmers	Percentage	K-W value
FLD	Small (<2ha)	16	10.19	52.53**
	Medium (2-5ha)	53	33.76	
	Large (>5ha)	14	8.92	
	Total	83	52.87	
Non-FLD	Small (<2ha)	9	5.73	49.49**
	Medium (2-5ha)	53	33.76	
	Large (>5ha)	12	7.64	
	Total	74	47.13	

** = Significant at 1% level of significance

Table 4 Correlation between independent and dependent variables

Type of farmers	'r' value	
	Adoption	Productivity
Age	-0.10 NS	-0.022 NS
Education	0.013 NS	0.018 NS
Farm size	0.161*	0.193*
Agricultural Experience	-0.32 NS	-0.055 NS
Area under castor	0.077 NS	0.107 NS
Number of other crops	0.163*	0.178*
Number of family labours	0.091 NS	0.140 NS
Castor training programmes	0.218**	0.209**
Social participation	0.048 NS	0.07 NS
Experience with number of cultivars	0.193*	0.17*
Contact with research organization	0.090 NS	0.124 NS
Contact with extension agriculture	-0.007 NS	-0.042 NS

*=significant at 5%l level and **=significant at 1% level of probability; NS=Non-significance

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Resource-use management of castor growers in Gujarat

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Abstract

An assessment of resource-use management (RUM) behaviour of castor growers was done in Gujarat, through a survey during January 2010 with 180 castor growers selected by proportionate random sampling procedure. The RUM behaviour of the overall respondents was medium to high. It was low to medium for farmers with small size of land holdings and medium to high for farmers with medium and large size of land holdings. Among the nine indicators of the scale to measure RUM behaviour, nutrient management, disease management, irrigation management and soil-moisture management had positive and significant contribution towards castor productivity. Strategies for efficient management of the indicators that contributing significantly to productivity are to be

popularized among the castor growers to enhance castor productivity in Gujarat through frontline demonstrations (FLDs), training programmes and awareness campaigns/field days, publicity materials (leaflets, folders) and mass media (AIR, television). Efforts are needed to improve the overall RUM behaviour of farmers with small size of land holdings.

Keywords: Resource-use management, castor growers, Gujarat

Introduction

Efficient management is vital for success or failure of any enterprise and so to agriculture as an enterprise too. Success of any farm depends upon the efficient management of available resources by the farmer. Castor is one of the important non-edible oilseed crops of the country that has been grown under two contrasting environments. One among them is irrigated environment with resource-rich input management conditions of Gujarat, Rajasthan and Haryana and the other being rainfed environment with resource-poor input management conditions of Andhra Pradesh, Karnataka, Tamil Nadu and Orissa (Raghavaiah *et al.*, 2006). The results of FLDs in castor conducted at varied agro-ecological conditions in different castor-growing states indicated that there exists a considerable yield gap between the improved protection technologies of castor and the farmers' practices under real farm situations (Venkattakumar and Hegde, 2009). Bridging the yield gaps can be achieved by improving the RUM behaviour of castor growers. To improve the RUM behaviour of castor growers, assessment of present RUM behaviour of castor growers as a benchmark is, obviously, a pre-requisite. In order to assess the RUM behaviour of castor growers under irrigated conditions, a study was conducted at major castor growing districts of Gujarat with the following objectives:

- Explore the profile of castor growers in Gujarat
- Assess the RUM behaviour of castor growers, the associated determinants in Gujarat
- Suggest strategies to improve the RUM behaviour of castor growers in Gujarat

Materials and methods

A planned survey was conducted to assess the RUM behaviour of castor growers, during January 2010 at Banskantha, Sabarakantha and Mahesana, the major castor growing districts of Gujarat (Damodaram and Hegde, 2007). A total of 180 castor growers selected through proportionate random sampling procedure were the sample of the study. Data pertaining to demographic details of the respondents and their RUM behaviour were collected through personal interview method, using a well structured data collection tool. The tool included a standardized scale to measure the RUM behaviour of castor growers in all production situations of the country with 52 statements under 9 indicator categories against a four-point response continuum. The data thus collected was coded, tabulated and subjected to descriptive statistics viz, mean, standard deviation (SD), Kruskal-Wallis (K-W) test, simple correlation and multiple regression. The results of such analyses are detailed in this paper.

Results and discussion

Distribution of respondents according to their RUM behaviour: Analysis of RUM behaviour of respondents using mean and SD measures revealed that most of the respondents (94%) with small size of land holdings had low to medium level of RUM behaviour, whereas most of the respondents with medium (94%) and large (93%) size of land holdings had medium to high level of RUM behaviour (Table 1). This trend had resulted in medium to high level of RUM behaviour of the overall respondents. However, the results of χ^2 analysis indicated that the association between distribution of respondents based on their size of land holdings and their respective RUM behaviour was highly significant. These results imply that the RUM behaviour of castor growers with small size of land holdings has to be improved through need-based extension strategies. Most of the respondents (83%) possessed small to medium size of land holdings and the results of K-W test implied that there was highly significant difference between respondents with small, medium and large size of land holdings. As far as the experience in agriculture is concerned, most of the respondents (78%) were in low to medium category and there was highly significant difference observed between respondents with low, medium and high level of farming experience. Most of the respondents (80%) had education up to middle school level. However, there was no significant difference among the respondent categories with different educational status with respect to their RUM behaviour. Majority of the respondents (68%) were supervisors as far as their nature of agricultural participation and there was highly significant difference among four different categories of respondents according to their nature of participation in agriculture with respect to their RUM behaviour.

Distribution of respondents according to indicator-wise RUM behaviour: Indicator-wise analysis of RUM behaviour of respondents using mean and SD measures revealed that most of the respondents had low to medium level of Land management (84%), seed management (85%) and weed management (75%) behaviour (Fig.1). Majority of them had medium level of nutrient (79%) and pest management (56%) behaviour. The RUM behaviour of most of the respondents was medium to high towards cropping system management (78%), soil-moisture management (91%), disease management (91%) and irrigation management (91%). Overall, most of the respondents (85%) had medium to high level of RUM behaviour. These results revealed that the RUM behaviour of the respondents towards the inputs like land and seeds and management of weeds has to be improved.

Contribution of RUM behaviour towards castor productivity: Multiple regression analysis between the indicators of RUM and castor productivity of the respondents implied that among the nine indicators of RUM behaviour, nutrient management, disease management and irrigation management had positive and significant contribution towards castor productivity at 1% level of probability, while soil-moisture management had positive and significant contribution towards castor productivity at 5% level of probability (Table 2). However, the indicators land management, cropping system management, seed management, weed management and insect-pest management had no significant contribution towards castor productivity. These results conclude that efficient management of diseases of castor, irrigation in castor, nutrient application and soil moisture management will result in enhancement of castor productivity under the given conditions of the study area.

Relationship between independent and dependent variables: The results of simple correlation analysis implied that among the demographic variables of the respondents, age, income from agriculture and income from other sources had positive and significant relationship with RUM behaviour of the respondents at 1% level of probability, while farm size and nature of agricultural participation had positive and significant relationship at 5% level of probability. However, the variables education, farming experience, experience in castor cultivation, number of other crops grown, number of family labour, time spent on agriculture and number of training programmes participated had no significant relationship with RUM behaviour of the respondents.

Conclusions

There was significant difference between castor growers with small, medium and large size of land holdings with respect to their RUM behaviour. Over all, there was medium to high level of RUM behaviour exhibited by the respondents. Effective management of irrigation, nutrients and diseases in castor are to be followed by the castor growers in irrigated regions of Gujarat to have enhanced productivity and resultant profitability in castor cultivation and these strategies are to be popularized among castor growers through training programmes and awareness campaigns/field days, publicity materials (leaflets, folders) and mass media (AIR, television). Experienced castor growers with higher income and social status and with large size of land holdings may be imparted training on effective RUM management strategies and these trained personnel may be utilized as contact farmers to influence the fellow castor growers to have better resource-use management in castor cultivation. FLDs on nutrient, disease and irrigation management aspects may be conducted through castor growers with higher experience, income and social status and with large size of land holdings as demonstration farmers for popularization. The above-mentioned strategies are to be highlighted, during the training programmes for officials of development department, so that they in turn can transfer this information to the castor growers.

Table 1 Distribution of castor growers based on their RUM behaviour (N=180)

Level of RUM	Farmers' categories (No.)				Mean	SD
	Small	Medium	Large	Total		
Low	19	4	2	25		
Medium	59	45	25	129		
High	5	18	3	26		
Total	83	67	30	180	277	32
Mean		17				
SD		0.7				
χ^2 Value			21.399**			

(Small=up to 2 ha; Medium=2- 5 ha; Large=more than 5 ha area)

Table 2 Contribution of RUM behaviour of castor growers on productivity

Indicators of RUM	Unstandardised coefficients	
	B Value	Standard Error
Constant	-0.5477.50	1081.65
Land management	15.59 NS	40.92
Cropping system management	19.32 NS	35.91
Seed management	3.74 NS	5.63
Soil-moisture management	53.40*	32.35
Nutrient management	10.44**	3.43
Weed management	8.81 NS	54.45
Insect-pest management	12.09 NS	15.97
Disease management	135.23**	23.45
Irrigation management	117.38**	32.33

(NS = Non significant; * = Significant at 5% level; ** = Significant at 1% level)

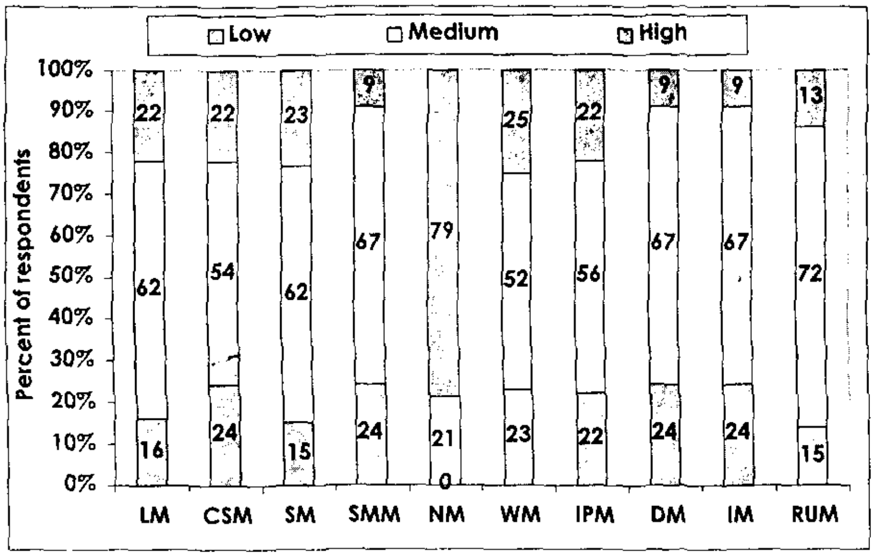

Fig. 1. Distribution of respondents according to indicator-wise RUM behaviour

(LM-Land management, CSM-Cropping system management, SM-Seed management, SMM-Soil moisture management, NM-Nutrient management, WM-Weed management, IPM-Integrated pest management, DM-Disease management; IM-Irrigation management; RUM-Resource-use management)

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Farmers' participatory varietal selection in castor

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Abstract

Participatory crop improvement (PCI) is important in the context of poor adoption of modern varieties. Varieties/hybrids selected from participatory crop improvement programmes are likely to be broadly adopted, stress tolerant and acceptable to farmers. Farmers participatory varietal selection in castor was carried out in the onfarm trials conducted at Tapioca and Castor Research Station (TCRS),Yethapur with participation of 100 farmers from seven blocks in three districts. Total of two new castor hybrids and two check hybrids were subjected to farmers participatory evaluation. The Kendall coefficient of concordance (W) was used to assess the concordance among rankings by the farmers. The co-efficient of concordance among farmers was highly significant in all the eight sets of participatory varietal evaluation trials. At all the locations, all the farmers except a few opted for the new castor hybrid YRCH 509 (YRCH 1), as their choice. The farmers observed earliness, compact and highly productive pistillate spike, high branching, lesser time lapse between any two order of spike, compact and short plant type and escape from *Botrytis* in early sown conditions and higher seed yield as the reasons for selecting YRCH 509 (YRCH 1) as the hybrid of their choice.

Keywords: *Castor, participatory varietal selection*

Introduction

Crop improvement plays an important role in development and strengthening of agricultural system. Close participation of farmers enhance the success rate of crop improvement system. It is believed that participatory crop improvement (PCI) possesses some essential advantages over formal crop improvement, such as better definition of selection criteria and better targeting of environmental conditions (Witcombe *et al.*, 2001).

Castor is an important industrial oilseed crop of the country. The area under castor in Tamil Nadu is about 13,900 ha. Castor in Tamil Nadu is mainly cultivated in rainfed ecosystem with low productivity of 322 kg/ha. A characteristic of rainfed castor in Tamil Nadu is a large year to year fluctuation in production because of unreliable monsoon and outbreak of *botrytis* grey mold disease in some years, which causes up to 80% yield loss. As a result the adoption rate of improved varieties is low and productivity is as low as 322 kg/ha. PCI is important in the context of poor adoption of modern varieties. Success of new crop varieties depends upon quick adoption. Often it is rather slow in marginal environments, where rainfed castor is *being cultivated. Many a times the improved varieties from the breeder fail due to the reason that farmers perceptions* change over time. Varieties/hybrids selected from participatory crop improvement programmes are likely to be broadly adopted, stress tolerant and acceptable to farmers (Atlin *et al.*, 2001). In this context, farmers participatory varietal selection in castor was carried out at TCRS (TNAU), Yethapur.

Materials and methods

A total of 100 on-farm trials were conducted from rainy season of 2006 to 2008 and spread over seven blocks of three districts viz., Namakkal, Erode and Dharmapuri districts of Tamil Nadu. The above locations represent predominantly castor growing regions of Tamil Nadu under rainfed ecosystem. In each block, two to three villages were selected to conduct the trials. In each block, all the participatory farmers encouraged to visit all the on farm trials in that block to make varietal selections. For example in Namagiripettai block of Namakkal district in 2006, total of 10 onfarm trials were conducted. Hence, all the ten farmers who have conducted on-farm trials were encouraged to visit all the ten trials and make varietal selections. In all the onfarm trials, two new castor hybrids YRCH 509, YRCH 541 and two checks such as TMVCH 1 and GCH 4 were evaluated. All the four hybrids were coded and farmers allowed to make their own evaluation, regarding suitability for local conditions, drought and *botrytis* incidence. Farmers also evaluated the hybrids for yield and yield components and duration.

The trials were unreplicated completely randomized block design in farmers fields. Farmers evaluated the various hybrids at critical phenological periods such as at 50% flowering, primary spike stage, secondary and tertiary spike stage, etc. Farmers ranked the hybrids based on their personal sets of selection criteria including yield and yields components. In addition, data on days to 50% flowering yield components, yield and pest and disease scores were recorded. Besides the ranking, farmers commented on the characteristics they liked or disliked in the varieties and the reasons underlying their ranking. Since multiple rankings were involved, the Kendall coefficient of concordance (W) was used to assess the concordance among rankings as described by Kothari (1985). The null hypothesis for W (W = 0) is that the rankings are randomly attributed. This hypothesis was tested by calculating χ^2 = K (N-1)w and comparing its value with the critical value of χ^2 with N-1 degree of freedom. W value of '1' indicates unanimity among all rankers.

Results and discussion

The co-efficient of concordance among farmers was highly significant in all the eight sets of participatory varietal evaluation trials. This indicated that farmers rankings were not randomly attributed. Hence there is significant agreement in rankings assigned by different set of farmers. At all the locations except very few farmers, all the farmers opted for the new castor hybrid YRCH 509 (YRCH 1), as their choice. The farmers observed earliness, compact and highly productive pistillate spike, high branching, lesser time, lapse between any two order of spike, short plant type and escape from *Botrytis* in early sown conditions and higher seed yield as the reasons for selecting YRCH 509 (YRCH 1) as the hybrids of their choice.

The hybrid YRCH 509 (YRCH 1) recorded highest mean seed yield of 1969 kg/ha in 100 on farm trials conducted in six blocks spread over three districts during rainy season of 2006 and 2008. Farmers observed less or no *Botrytis* grey rot incidence in YRCH 509. This may be due to disease escape mechanism because of earliness in rainy season. Based on the performance of the new castor hybrid YRCH 509, in station trials, multilocation trials, adoptive research trials and on farm trials in the farmers fields, the hybrid was released for cultivation in 2009 as YRCH 1 for castor growing conditions of Tamil Nadu state.

Conclusion: The study revealed that farmers participation in varietal selection of castor, is highly effective in selecting a promising high yielding castor hybrid for release.

Table 1 Coefficient concordance among farmers rankings

District	Block	Year	No.of trials	No.of hybrids	No.of farmers	W
Namakkal	Namagiri pettai	2006	10	4	10	0.88**
Namakkal	Namagiri pettai	2007	10	4	10	0.67**
	Elachipalayam	2007	15	4	15	0.79**
	Mallasamutiram	2007	15	4	15	0.81**
Erode	Bhavani	2008	10	4	10	0.46**
Dharmapuri	Poonachi	2008	15	4	15	0.57**
	Morappur	2008	15	4	15	0.54**
	Kadathur	2008	10	4	10	0.48**

Table 2 Mean seed yield in the participatory varietal selection

District	Block	Year	No. of trials	Mean seed yield			
				YRCH 509	YRCH 541	TMVCH 1	GCH 4
Namakkal	Namagiri pettai	2006	10	2225	1720	1650	1750
Namakkal	Namagiri pettai	2007	10	2340	1410	1680	1544
	Elachipalayam	2007	15	2085	1350	1270	1675
	Mallasamuthiram	2007	15	1650	1425	1400	1320
Erode	Bhavani	2008	10	2105	1780	1650	1720
	Poonachi	2008	15	1800	1620	1450	1400
Dharmapuri	Morappur	2008	15	1650	950	1250	1300
	Kadathur	2008	10	2245	1120	930	1180
Weighted mean of 100 trials			100	1969	1405	1396	1473

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Castor - A major exportable agricultural commodity

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Castor is an important non-edible oilseed crop and is grown especially in arid and semi arid regions. It is cultivated in 30 different countries of which India, China, Brazil, Ethiopia and Thailand are the major castor growing countries accounts about 90% of the Worlds' production. However, in early 90's Brazilian farmers moved away to more lucrative cash crops and surge in domestic demand in China made them net importers leaving India to meet the global demand. India alone produce about 70% of the castor production of the world (Table 1). Thus, India is the world largest producer of castor seed and meets most of the global demand for castor oil.

Castor oil enjoys tremendous demand world-wide estimated at about 220000 t/annum. The current consumption of castor oil and its derivative in the domestic market is estimated at about 100000 t. India is also the biggest exporter of castor oil holding about 70% share of the international trade in castor oil. When major countries of the world continue to promote production and trade in value added products, India has been content with export of raw materials with limited value addition despite an expanding world market. With the annual export of 2 to 3 lakh tonnes of castor oil, India dominates in the global castor oil trade (Table 2). Even as the country is chronically short of vegetable oils, castor oil has traditionally been as export oriented commodity. Though India is meeting most of the world requirement of castor oil, we are not capitalizing it. India still continues to export the castor oil in cheaper prices. Indian buy back its own castor oil as formulated products and its derivatives at many times the price of the oil. Much of the value addition after processing of castor oil is done overseas and a handful of international trading houses that regularly buy the oil in bulk from India are able to reap windfall gains because of their tie up with the end users of derivative products. In the process of bulk export of a primary commodity, India castor seed growers and oil exporters both lose out. Its versatility and a large number of down-steam products make consumption demand of castor oil, price-inelastic. Whatever be the price, overseas buyers are bound to buy castor oil from India, because of large export surplus we generate and continuing strong demand. In the last three years, prices have been fluctuated in a wide range between ₹ 550-1200 a tonne.

Table 1 Castor production by major castor growing countries of the world

Country	2004-05	2005-06	2006-07	2007-08	2008-09
India	793	991	762	1053	1124
China	250	250	240	210	220
Brazil	139	169	92	113	121
Ethiopia	15	15	15	6	7
Thailand	10	10	11	11	11
World	1258	1488	1140	1492	1581

Table 2 Exports of castor oil from India

Year	Volume (Lakh tonnes)	Value (₹ in crore)
2004-05	2.48	977
2005-06	2.33	845
2006-07	2.71	986
2007-08	2.57	1151
2008-09	3.31	1942

Although castor oil is not edible, it is more versatile than other vegetable oils as it is widely used as a starting material for many industrial products. The hydroxyl functional group on the twelfth carbon in the 18-carbon fatty acid chain of the monosaturated ricinoleic acid content of castor oil is the unique in nature. This functional group causes ricinoleic acid (and castor oil) to be unusually polar and also allows chemical derivatization, that is not practical with most of the other seed oil. It is the hydroxyl group which makes castor oil and ricinoleic acid valuable as chemical feed stocks for various industrial purposes and commands a higher price than the other vegetable oil. Castor is a versatile renewable resource having vast and varied application such as lubricating grease, surfactants, surface coatings, telecom engineering plastics and rubber chemicals. The primary use of castor oil is as a basic ingredient in the production of nylon 11, nylon 6-10, Jet engine lubricants, heavy duty automotive greases and inks, polyurethanes, soaps, polishes, fly papers, paints and varnishes (Ogunniyi, 2005). The castor cake is mainly used as a fertilizer. It is also used as raw material for a number of products in the pharmaceutical and cosmetic industries.

In order to reap the benefits of being the largest producer of castor in the world, castor oil export in bulk should be discouraged and export of value added products like hydrogenated castor oil, dehydrated castor oil, hydroxyl stearic acid and sebacic aid should be encouraged. Monitoring growth, regulated trading and unified vision among industry participants would be more helpful to exploit natural advantage (Chandrashekhar, 2008). The castor production can also be increased further in the country with the cultivation of crop in non-traditional regions such as eastern India and northern India such as U.P. and Haryana and fixing remunerative price for the castor produced to the castor growers through organized spot markets. Imposing of duty on bulk export will not only discourage the castor oil exporters but also generate huge revenue which can be ploughed back into the sector to improve castor seed yields, raise production, help processing units, modernize and tap export markets for derivatives. All round efforts are also needed to change the attitude of international trading houses in sourcing the raw castor oil in bulk from India at low price and add value overseas to earn large profit.

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Ethnic uses of castor (*Ricinus communis* L.) in eastern ghats, India

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Abstract

The use of diverse plant species is an integral part of ethnic medicine of tribal communities. The Eastern ghats are endowed with 2,600 species of higher plants including 160 species of cultivated plants and this region is inhabited by nearly 54 tribal communities. Castor (*Ricinus communis* L.) is an important oilseed crop with significant endemic landrace diversity available in the eastern ghats region. Ethno-botanical information on castor documented from informal consultations with tribal healers, villagers, herbal vendors during several exploration missions conducted for the collection of agro-biodiversity by the National Bureau of Plant Genetic Resources in this region is highlighted. The ethno-medicinal practices by the tribal communities and additional information obtained from literature have been presented. A comparative account on uses of castor in folk medicine, *Ayurveda* and *Unani* systems of medicine is also tabulated.

Keywords: Castor, ethnic uses, eastern ghats

Introduction

Eastern ghats region is endowed with a spectrum of biological species, geological formations and ethnic tribes. More than 2,600 plant species of angiosperms, gymnosperms and pteridophytes including 160 species of cultivated plants are reported to be occurring in the Eastern ghats region which includes 454 endemic species belonging to 243 genera and 78 families

(Sudhakar Reddy *et al*., 2002). Castor (*Ricinus communis* L.) is an important oilseed crop in India and significant endemic landrace diversity exists in the eastern ghats region which include *Amudalu, Amudamu, Chettu amudam, Chitti amudam, Kondangi amudalu, Konda amudam, Neronda amudam, Pedda amudam, Vonta amudam*, etc. These have been cultivated by the tribal and other communities over centuries.

The eastern ghats region is inhabited by nearly 54 tribal communities, which constitute nearly 30% of total population (Chauhan, 1998). Most of the tribal inhabitants are small and marginal farmers and engaged in slash and burn shifting cultivation which is not at all productive or sustainable because of the short cycle (Chauhan, 1998). The long interaction between people and plants has resulted in the accumulation of a vast storehouse of knowledge about the plant resources including castor diversity and its traditional use in folk medicine. Many tribal communities practice local traditional health remedies using castor and other medicinal herbs to cure various ailments which is sustained through generations by world of mouth. There is an urgent need to recognize and document the folk knowledge on biological resources. This article discusses the ethnic uses of castor including medicinal knowledge systems that are prevailing among the tribal communities inhabiting the eastern ghats.

Materials and methods

National Bureau of Plant Genetic Resources, Regional Station, Hyderabad is the nodal organization for the collection, evaluation, conservation, documentation of agro-biodiversity including castor genetic resources in the south east coastal zone of India. It has organized more than 100 germplasm surveys for the collection of agri-horticultural crops in this region and collected over 11,000 accessions including over 240 accessions of castor germplasm. A database on these accessions is being maintained at the centre, which has been consulted for the study. Data on tribal settlements were collected from the forest department, economics and statistics bureau and NGO organizations working with tribal communities and other relevant literature. Information about the ethno-botanical uses and folk medicine knowledge on castor biological resources were compiled during the several exploration missions conducted in this region. Local vaidyas (gurappas), hakims, tribal headmen, magico-religious practitioners and villagers were interviewed informally during exploration missions conducted in the south east coastal zone of India. Literature on ethno-botany and folk medicine was also consulted (Kirtikar and Basu, 1899; Antonio and Antonio, 1982; Anonymous, 1986; Vedavathy *et al*., 1997; Ramarao Naidu and Seetharami Reddy, 2008).

Results and discussion

Native diversity in castor predominantly occurs in Karimnagar, Khammam, Nalgonda, Nellore, Mahaboobnagar, Prakasam, Rangareddy and Visakhapatnam districts in Andhra Pradesh. Khammam, Ranga Reddy, Mahaboobnagar and Visakhapatnam are principally endowed with diversity in perennial castor germplasm. The study resulted in bringing out various ethno-botanical and medicinal practices using castor by the tribal communities inhabiting this region. The various ethnic uses of castor with special reference to folk medicine are detailed below:

Ethno-medicinal uses of castor

Abortion: Leaf paste of castor is applied to vagina to terminate 3-5 months of pregnancy

Anti-partum treatment: Calotropis gigantea flowers fried in cow's ghee is made into decoction and 3-4 spoons of this given to the patient suffering from hard labour pains. Castor oil is applied to the cervix every 15 minutes.

Boils: Warm leaf paste is bandaged on the affected part to effect a cure.

Conjunctivitis: Leaf decoction of *Achyranthes aspera* mixed in castor oil is anointed on the head and applied to the body an hour before headbath.

Cuts and wounds: *Boerhaavia diffusa* leaf paste prepared by mixing a pinch of salt and turmeric is applied on the wound using castor oil base.

Dandruff: Leaf juice of *Eclipta prostrata* mixed with castor oil is applied on the head.

Ear-ache: Garlic bulbs are boiled in castor oil and filtered. Two or three drops of the oil are instilled in the ear.

Eczema: Powder of Indian birthwort (*Aristolochia indica*) along with the oil prepared from boiling *Datura stramonium* leaf juice in castor oil is applied externally.

Family planning: After menses, first day one seed is administered orally in empty stomach followed by two beans on the 2^{nd} day and three beans on the 3^{rd} day and again one bean on 4^{th} day is taken for temporary family planning by the tribals.

Filariasis: Seed paste applied on affected part (feet)

Gangrene: Castor oil is poured on to a copper plate/vessel and exposed to sunlight for 21 days. The precipitate is then taken and applied externally.

General laxative and pre-treatment for all diseases: Castor oil boiled with *Terminalia chebula* (Karakkaya), *Azadirachta indica* (Neem), *Butea monosperma* (Moduga), *Alpinia galanga* (Dumparashtramu) are given as a prelude to major treatment of diseases. *Chitti amudamu*, a local landrace of castor is used by tribals for cleansing bowels in human beings (mainly for colic in infants)

General skin ailments: Castor oil mixed with copper sulphate is used to treat various skin ailments.

Hair tonic: Castor oil with *Hemidesmus indicus*, manga kaya and narlingi bark are being used as hair tonic. Leaf extract of *Abrus precatorius* boiled in equal quantity of castor oil is applied to hair regularly for hair growth. Fruit juice of Gmelina asiatica mixed in castor oil is boiled and used as hair tonic.

Head ache: Warm leaf paste of castor applied to head to cure *vatha* based head-ache.

Hydrocoel: Leaves of *Caesalpinia crista* warmed in castor oil are bandaged on the testicles

Inflammation and swellings: Pounded leaves of *Alangium salvifolium* are cooked in castor oil and bandaged on the affected part.

Jaundice: Tender leaf paste along with coconut water is orally admitted to the patients suffering from jaundice. Leaves of *Centella asiatica*, Henna and castor are taken in equal quantities and ground into paste by mixing with jaggery and rice husk. Castor oil bath is recommended after cure.

Joint pains: Leaves of *Calotropis gigantea* warmed after applying castor oil are put on the affected part and bandaged. *Erythrina indica* leaves warmed by applying castor oil are bandaged on the affected region.

Oral contraceptive: castor beans (2-4) are swallowed from the 3rd day of menses for a week as a temporary measure for birth control among the tribal communities.

Paralysis: Leaves with petioles are burnt on live coals and ash is extracted. A table spoonful of the ash mixed with honey is given as diet.

Piles and fistula: Castor oil ground with niger seed is applied externally to cure piles and fistula.

Psoriasis: *Aristalochia bracteata* leaf along with the rhizome of *Curcuma domestica* and pepper seed are made into a paste with cow's urine and boiled in castor oil. The oil is applied on the affected part regularly.

Purification of herbal drugs: The soot (*massi*) obtained by burning the lamp with castor oil is used for the purification of herbal drugs (*shuddi*) and making pills.

Removal of thorns/prickles embedded in body: Castor oil mixed with boiled rice and turmeric used for the removal of thorns/prickles from the body and used as an anti-septic.

Rheumatism: Leaves of *Cardiospermum halicacabum* warmed by applying castor oil are bandaged on the tumours and rheumatic swellings. *Calotropis gigantea* leaves warmed by applying castor oil and bandaged on the swollen parts. Castor oil mixed with boiled rice and turmeric applied to rheumatic swellings and arthritic swellings. Crushed leaves of *Delonix alata* warmed by using castor oil are bandaged on the swollen parts.

Scorpion bite: Leaf paste and garlic ground with kerosene and applied to the swellings.

Sexually Transmitted Disesaes (STD): Castor oil with arsenics and copper sulphate are used in the treatment of STD (syphilis and gonorrhea)

Snake and insect bites: Leaf paste and garlic ground together are applied at the mouth of sting.

Sterilization: 4-5 seeds are swallowed from the fifth day of menstruation. This is continued upto 7 days. Spoonful of the paste from the tender leaves mixed with *Tragia* leaves is given with rice washed water from the third day of delivery upto sixth day.

Stomach pain: Leaves warmed on live coals are put on the stomach

Tooth ache: Latex is applied to the gums

Ethnobotanical uses of castor other than folk medicine

Cooking: Castor oil is used for cooking purposes by almost all the tribal communities

Lamp oil: Castor oil is being used as lamp oil and the soot obtained by burning lamps with castor oil is used as eyeliner/kajal and bindi purposes.

Silkworm rearing: Leaves are used to rear Eri-silkworms; Leaves and stems are used to rear (Miris); Cultivated for rearing Endi under *Jhuming* cultivation (Karbis) (Hajra and Baishya, 1981)

Socio-religious: Castor is one of the plants associated in socio-religious ceremonies of *mundas* connected with hunting. The ceremony of cutting a castor oil tree (*Risa jaradaru*) is known as *Pagu-Ma* during the hunting feast (Gupta, 1981)

Cattle feed: Leaves of castor are being used as cattle feed

Table 1 Medicinal uses of castor in various systems of medicine

Ailment	*Plant part used*	*Folk medicine (Tribal group/s)*	*Ayurveda*	*Unani*
Abortion1	Root	Savara, Jatapu, Gadaba, Konda dora, Kutiya		
Alterative2	Seed oil		√√	
	Root bark			√√
Amenorrhoea2	*seed oil*			√√
Anal troubles2	Flowers		√√	
Anemia2	Tender shoots	√√		
Anthelmintic2	Seed oil		√√	
Anticancer2	Root and stem			
Antiprotozoal2	Root and stem			
Antiviral2	Leaf			
Aphrodisiac2	Seed; Seed oil		√√	
Appetiser2	Fruit		√√	
Ascites2	*Root*		√√	
	Seed oil		√√	√√
Asthma2	Root		√√	
	Seed oil			√√
Back pain2	Seed oil		√√	
Biliousness2	Leaf		√√	
Body swellings3	Leaf paste	Khasi, Jaintia		
Boils and sores2,4	Leaf poultice			
	Seed oil			√√
Bronchitis5	Root		√√	
Burns5	Leaves			√√
Carminative5	Root		√√	
Cathartic4,5	Seed oil		√√	
Convulsions5	Seed oil		√√	
Diuretic2	Seed			
Dropsy5	seed oil			√√
Earache5	Leaves		√√	
Edema6	Tender shoots	Nomadic groups		
Elephantiasis5	Seed oil		√√	
Eructations5	Root		√√	
Eyes7	Leaves	Guttikoyas, Koyas		
Fever5	Root	Savara, Jatapu, Gadaba, Kondadora, Kutiya	√√	
	Seed oil		√√	
Galactagogue5	Leaves			√√
Glands5	Root		√√	
Glandular tumours5	Flowers		√√	
Head5	Root		√√	
Headache5	*Leaf*		√√	
Heart5	Seed oil		√√	
Hypoglycaemic2	Root; Stem; Leaf			
Inflammations5	Root		√√	
	Seed oil		√√	√√
Jaundice1	Tender leaves	Savara, Jatapu, Gadaba, Kondadora, Kutiya		
Leprosy5	Root; Seed oil		√√	
Liver diseases5	Fruit		√√	
	Seed oil			√√
Lumbago4,5	Root	√√		
	Seed oil		√√	√√
Malaria1	Leaves	Savara, Jatapu, Gadaba, Kondadora, Kutiya		
Night blindness5	Leaves		√√	
Osteoarthritis8	Erandamoola			
Pains5	Root; Fruit		√√	

	Seed oil			√√
Piles5	Fruit		√√	
	Seed oil			√√
Purgation1,4,5,9	*Seed*	*Savara, **Jatapu, Gadaba, Kondadora**, Kutiya*		
	Seed oil	Irulas		√√
	Root bark			√√
Paralysis4,5	seed oil			√√
Diseases of Rectum5	Root		√√	
Rheumatism5	Root	Savara, Jatapu, **Gadaba, Kondadora, Kutiya**		
	Leaf paste	Khasi, Jaintia		
	Seed oil			√√
Rheumatoid arthritis8	Erandamoola		√√	
Ringworm5	seed oil			√√
Skin diseases5	Seed oil	√√		
	Root bark			√√
Spleen diseases5	Fruit		√√	
Strangury5	Leaf		√√	
Tumours5	Fruit; Seed oil		√√	
Typhoid5	Seed oil		√√	
Vaginal pain5	Flowers		√√	
Worms5	Leaves		√√	

1. Rama Rao and Reddy, 2008; 2. Chandel et al., 1996; 3. Kharkongor and Joseph, 1981; 4. Anonymous, 1986; 5. Kirtikar & Basu,1899; 6. Bhakshu & Raju, 2008; 7. Pandravada, 1996; 8. Prasad et al., 2008; 9. Abraham, 1991

Manure: *Castor cake is used as manure.*

Pest control: To control storage pest in coffee, coffee beans are treated with a mixture of castor oil and groundnut oil by the *Malayali* tribes of Shervaroys (Mohapatra *et al.*, 2009).

Intercrop: *Turmeric+Castor intercropping is being practiced by tribes (Malayali) to control capsule borer in castor* (Mohapatra *et al.*, 2009).

Lubricant: Castor oil is being used as a lubricant in diesel engines

James A Duke (1983) in his handbook of energy crops (available at http:/ /www.hort.purdue.edu/newcrop/duke_energy /ricinus_communis.html) has listed the various uses of folk medicine. Various uses of seed oil by the *Irulas* were reported *by Abraham (1981).*

India has an ancient record of use of plants in the indigenous systems of medicine (Ayurveda, Unani and Siddha) that date back over 5000 years. Ayurveda records over 8000 herbal remedies. About 6000 plants are used in traditional, folk and herbal medicines in India (Huxley, 1984). The comparative use of castor in folk, *Ayurveda* and *Unani* systems of medicine is listed in Table 1.

The present study reveals that castor still plays a vital role in the primary health care of the people. Developmental activities namely, construction of dams, encroachment of vast areas of forest land, shifting cultivation, mining operations and industrialization have depleted natural populations of castor especially the perennial types naturally occurring in tribal pockets. Integrated efforts towards modernizing the tribal groups have changed the life style of the younger generation who are thus sceptical towards traditional healing practices, leading to overall erosion of ethno-botanical knowledge including that of castor, its cultivation and utilisation. Given the diverse medicinal utilities that are attributed to this wonderful plant, the diversity of castor in natural habitats needs to be assessed to implement conservation strategies apart from the conventional ex-situ approaches. Further, it is timely to take up research to systematically and scientifically validate the various claims regarding curative active principles and pharmacological action of various parts of the castor plant.

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Integrated nutrient management (INM) in castor + groundnut intercropping system : An on-farm experience in Junagadh, Gujarat

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Abstract

On-farm trials (OFTs) were conducted on Integrated Nutrient Management (INM) in castor + groundnut (1:3) intercropping system (ICS) over a period of three years in four villages of Junagadh, Gujarat. The trials were designed with three options in order to provide farmers an opportunity to compare, evaluate and choose themselves the best option based on their own criteria. The options were T_1 = farmers practice of nutrient management (N and P through DAP), T_2 = recommended dose of N, P and K (12.5:25:20 for groundnut and 20:40:40 for castor) by using ammonium sulphate, single super phosphate, muriate of potash and $T_3 = T_2$ + application of gypsum @ 500 kg/ha and seed treatment of groundnut with phosphate solubilizing microorganism @ 4 g/kg seed. The farmers preferred third option due to high yields, net returns and benefit-cost ratio. The large farmers were more convinced and adopting the same but, the small farmers even though convinced by the potential of the option three, they were not adopting due to high cost of cultivation. The farmers' perceptions on the preference of castor based ICS indicated that small farmers attributed highest priority to the risk management followed by relief from abiotic and biotic stresses and duration of the component crops, while the medium category farmers attributed highest priority to risk management followed by revival of crops after relief of rains and relief from biotic and abiotic

stresses. The large farmers attributed highest priority to duration of the component crops followed by risk management and relief from biotic and abiotic stresses.

Keywords: Farmers' perceptions, on-farm trials, castor + groundnut, Gujarat

Introduction

Groundnut is an important oilseed crop grown by the farmers of Junagadh, Gujarat. Castor + groundnut (1:3) intercropping is the traditional system followed by farmers of the region. The benefits of this system were, increase in total yield over sole crop and compensating the risk of crop failure during aberrant rain fall years. One of the main reasons for such advantage is that the component crops are able to use resources efficiently, so that when grown together they supplement each other and make better use of resources than growing separately. Besides increasing productivity of the component crops, intercropping also reduces weed competition, infestation of insect pests and diseases in the system and improves soil productivity. In aberrant rainfall years, intercropping seems to be a good preposition to sustain the livelihood security of farmers. Besides, in normal season, it increases the farm income and aims at efficient utilization of solar energy, moisture and nutrients (Gujjari *et al.*, 1994).

An indiscriminate use of fertilizers by farmers was observed in castor + groundnut (1:3) ICS. In addition, diammonium phosphate (DAP) was most commonly used fertilizer that does not contain S, essential for oil synthesis in groundnut. Most farmers of the region were not applying gypsum that contains Ca required for pod filling in groundnut. All these practices caused nutrient imbalance, especially micro nutrient status of the soil, upset the balance of soil micro flora and decreased fertilizer use efficiency. If such practice continues, in the long run, productivity of soil will deteriorate and farmers in the area cannot sustain their livelihood. The indication of soil health breakdown is reflected in the increasing incidence of soil borne diseases of groundnut. Therefore, the combined and balanced use of organic, chemical and biological sources of fertilizers could ascertain the balanced nutrition to the crops and sustain the productivity in the long run. Based on the experimental results at Directorate of Groundnut Research (DGR), on-farm trials (OFTs) were conducted with the objectives to assess the profitability of INM modules and farmers' perceptions on the preference of castor based ICS.

Materials and methods

After a preliminary survey of 24 villages, four villages *viz.*, Vadhavi, Zanjarda, Nandarkhi and Umatwada were selected based on highest area of groundnut. Farmers were randomly selected for OFTs from these villages taking due care to give equal representation to three categories of farmers *viz.*, small farmers (land holding of < 0.1 ha), medium (> 1 to 2 ha) and large farmers (> 2 ha). A total of 45 OFTs were conducted over a period of three years. Each trial was laid out in an area of 0.1 ha. The trials were designed with three options in order to provide farmers an opportunity to compare, evaluate and choose themselves the best option based on their own criteria. The options were T_1 = farmers' practice of nutrient management (NP through DAP), T_2 = recommended dose of N, P and K (12.5:25:20 for groundnut and 20:40:40 for castor) by using ammonium sulphate (AS), single super phosphate (SSP) and muriate of potash (MOP) and T_3 = T_2 + application of gypsum @ 500 kg/ha and seed treatment of groundnut with phosphate solubilizing micro organisms (PSM) @ 4 g/kg seed. To assess the best option, yield, cost of cultivation, gross monetary returns (GMR), net returns, cost-benefit ratio (CBR), added returns and added net returns were calculated based on partial budgeting technique (Birthal, 2003). Various methods such as focused group discussions, field visits, discussions and transect walks were used to elicit the feed back from the farmers.

Results and discussion

The results of OFTs (Table 1) indicated that the plot with option three i.e. application of gypsum and PSM along with recommended dose of fertilizer in the form of AS, SSP, and MOP increased the yield of component crops *viz.*, castor by 31% and groundnut by 27% as compared to farmers' practice. This also recorded 18% increase in GMR with CBR of 2.81. Even the option two i.e application of NPK in the form of AS, SSP and MOP was more beneficial than the plot with farmers' practice in terms of increase in yield of groundnut (18%) and castor (7%). The GMR of Rs.42479/ha, added returns of Rs.5621/ha and added net returns of Rs.3414/ha and CBR of 2.75, which were higher than the plot with farmers practice.

Different categories of farmers had differential perceptions on the preference for castor based ICS, which was evident from the mean perception scores (MPS). The small farmers attributed highest priority to the risk management with MPS of 4.71 (Table 2) followed by relief from abiotic and biotic stresses (4.41) and the duration of the component crops (4.26), while the medium category farmers attributed highest priority to risk management with MSP of 3.89 followed by revival of crops after relief of rains (3.81) and relief from biotic and abiotic stresses (3.38). The large farmers attributed highest priority to duration of the component crops (4.52) followed by risk management (4.38) and relief from biotic and abiotic stresses. The farmers' perceptions on the factors which influence the yield of ICS were rainfall distribution (96.8%), timely sowing of crop (100%), plant protection (84%), proceeding crop (76.6%), crop combinations (18.4%), crop geometry and plant nutrition (10.4%).

Conclusion

From castor + groundnut (1:3) ICS these trials, it can be concluded that application of recommended dose of NPK in the form of AS, SSP, and MOP along with gypsum and PSM has been more beneficial for castor + groundnut (1:3) ICS because AS, and SSP contains S, very essential for oil synthesis and gypsum contains Ca useful for peg formation in groundnut.

Hence, the combined use of organic, chemical and biological sources of fertilizers in appropriate proportions will ascertain the balanced nutrition to the crop and sustain the productivity in the long run. The ICS will play a vital role in risk management and thereby livelihood security of the farmers. It is important that the small farmers are to be encouraged for crop diversification through castor based intercropping systems to improve their livelihood security.

Table 1 Productivity potentials and profitability of INM in castor + groundnut (1:3) ICS

Economic indicators	Castor + groundnut ICS		
	T_1	T_2	T_3
I. Yield (kg/ha)			
Castor	692	743 (6.86)	910 (31.5)
Groundnut	1633	1927 (18.0)	2081(27.4)
II. Partial budget analysis (Rs./ha)			
GMR	36858	42479 (13.23)	43640 (18.4)
Added returns	-	5621	6782
Change in cost	-	1137	1352
Added net returns	-	3484	5430
BCR	2.57	2.75	2.81

Figures in brackets indicate the % increase over farmers' practice; T_1: Farmers practice; T_2: recommended NPK through SSP, AS and MOP; T_3:T_2 + Gypsum + PSM

Table 2 Farmers' perceptions of castor + groundnut based ICS

Farmers perception	Mean perception score			
	Small	Medium	Large	Overall
Domestic food and nutrition needs	3.85	1.70	3.14	2.85
Economic/risk management	4.71	3.89	4.38	4.31
Maximizing production	1.56	1.16	2.76	1.76
Relief from abiotic/biotic stresses	4.41	3.38	3.93	3.89
Capitalizing on later rains	2.74	2.24	1.90	2.31
Revival of crop after relief of rains	3.91	3.81	3.52	3.76
Influence of women	1.0	0.35	0.31	0.53
Short duration of the components crops	4.26	3.89	4.52	4.20
Ground clearance for next crop	0.21	0.03	0.03	0.09
Easy availability of seed	1.09	1.57	1.86	1.49
Easy method of adoption	0.18	0.08	0.14	0.13

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Traditional uses of castor (*Ricinus communis* L.)

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Abstract

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop. India has the maximum area and production under the crop. Andhra Pradesh, Orissa, Karnataka and Rajasthan are major castor producing states in India. The diversified uses of leaf, seed, oil, stem and bark are concealed in the traditional knowledge of different tribes. Hence an effort was made to document the knowledge and practices. Lambani communities are established in Karnataka, Maharashtra and Andhra Pradesh. Different tandaas living in Hosur, Sogal, Mallur, Dhupdal, Badli, Kaginal, Yakkundi, Karlkatti, Dhupdaal, Nallur, Rudrapur, Karimani, Ramapur, Somapur, Subbapur and Katamali of Belgaum district grow castor as catch crop. They have vast traditional knowledge about castor. Medicinal practices by the tribal communities using the castor are for general laxative, birth control, anti-partum treatment, boils, conjunctivitis, cuts and wounds, dandruff, ear-ache, gangrene, and pre-treatment for all diseases, General skin ailments, hair health, head ache, cooling effect, inflammation and swellings, joint pains, paralysis, piles and fistula, insect bite, stomach pain, tooth ache , etc.

Keywords: Castor, traditional uses

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop of the arid and semi arid regions of the world, wherein India has the maximum area and production under the crop. In India, the crop is grown in an area of above 10.77 lakh ha with a total production of above 8.67 lakh tonnes. Andhra Pradesh, Orissa, Karnataka and Rajasthan are the major castor producing states in India.

Lambanis lead a gypsy life usually ascribed as nomadic; mainly inhabit the western Indian states including Karnataka, Maharashtra and Andhra Pradesh. Their traditional occupation is agriculture and trade. A part of this community set up in the northern Karnataka region mainly in Hosur, Sogal, Mallur, Dhupdal, Badli, Kaginal, Yakkundi, Karlkatti, Dhupdaal, Nallur, Rudrapur, Karimani, Ramapur, Somapur, Subbapur and Katamali of Belgaum district. These communities are referred as tanda/haadi/vaadi. They are about 10-15% of the village population. The tandas living in these areas are mainly small and marginal farmers engaged in shifting cultivation. As they own unfertile land, deep rooted crops are grown. Field beans, minor millets, bajra, etc., along with castor as catch crop are practiced by them. The people living here utilized various plant resources for their needs such as food, medicine and fodder. This long term practice of utilization has lead to vast store house of knowledge about the plant resources including castor diversity and its traditional use. Many tribal communities practice local traditional health remedies using castor and other medicinal herbs to cure various ailments (Table 1). These knowledge systems have been continuously sustained from one generation to the next by word of mouth over several centuries, a practice which is presently threatened due to culture diffusion, disintegration and globalization. Hence, an attempt was made to explore and document the traditional knowledge on castor oil in Lambani community.

Materials and methods

Local practitioners and villagers of the tribes residing in Hosur, Sogal, Mallur, Dhupdal, Badli, Kaginal, Yakkundi, Karlkatti, Dhupdaal, Nallur, Rudrapur, Karimani, Ramapur, Somapur, Subbapur and Katamali of Belgaum district were interviewed for the study. A focus group method was used to collect and document the knowledge and practices about diversified uses of castor with the help of open ended questionnaire. The informal interview was conducted on two visits and the data was gathered by a questionnaire. A total of 250 subjects were interviewed.

Results and discussion

The study recorded interesting uses of castor for various ailments which were traditionally followed by the tribe. These practices were found to be passed on from one generation to next. The various uses practiced by the tribe with special reference to health are detailed below:

Medicinal uses:

- Castor is used as laxative for cleansing bowels in adults and infants.
- Warmed castor oil is applied on the body by lactating women as it warms the body.
- Warmed castor oil is massaged on the breasts of the lactating women to have more milk secretion.
- For termination of pregnancy in first trimester - castor leaf paste is applied to vagina.
- Castor oil is applied to the cervix frequently for anti-partum treatment.
- Leaf is heated on pan and bandaged on the boil to cure.
- *Boerhaavia diffusa* leaf paste mixed with a pinch of salt and turmeric and is applied on the wound using castor oil base.
- *Castor oil is mixed in Achyranthes aspera and applied to the body and head an hour before headbath cures* conjunctivitis.
- Leaf juice of *Eclipta prostrata* mixed with castor oil applied on the scalp of the head cures dandruff.
- Castor oil together with garlic warmed, cooled and put in the ear to take care of ear ache.
- Consumption of castor beans in small amounts works well for family planning.
- Copper charged castor oil warmed nicely in sunlight used for gangrene treatment.
- Castor oil boiled with neem (*Azadirachta indica*) used as antiseptic for many diseases.
- Castor oil mixed with camphor is used to treat various skin ailments.
- *Castor oil with certain leaf extracts and fruit juices are used as hair tonic as it leads to healthy hair.*
- Warm leaf paste of castor applied to head to cure vatha based head-ache.
- Castor oil boiled with *Alangium salvifolium* and and used to treat inflammation and swellings.
- Tender leaf paste along with coconut water is orally admitted to the patients suffering from jaundice.
- Leaves and petioles are burnt and used for treating paralysis.
- *Castor oil ground with niger seed is applied externally to cure piles and fistula.*
- Castor oil mixed with boiled rice and turmeric applied to rheumatic swellings and arthritic swellings.
- Castor oil mixed with boiled rice and turmeric used for the removal of thorns from the body and used as an anti-septic.

- Crushed leaves of *Delonix alata* warmed by using castor oil are bandaged on the swollen **parts.**
- Leaf paste and garlic ground with kerosene and applied to the swellings of insect bites.
- Leaves warmed on live coals are put on the stomach to cure stomach pain.
- Latex is applied to the gums to heal up tooth ache.
- Castor oil is applied to feet in the summer to have cooling effect.
- Castor oil is used in place of coconut oil as termed inexpensive.

Other uses: Some other uses of castor are listed here.

- Castor oil is being used as a lubricant in diesel engines.
- Used as catch crop with field bean and bajra.
- Castor cake is used as manure.
- Castor leaves are used as cattle feed.
- Turmeric + castor intercropping is being practiced to control capsule borer in castor (Mohapatra *et al.*, 2009)
- To control storage pest in coffee, coffee beans are treated with a mixture of castor oil and groundnut oil (Mohapatra *et al.*, 2009).
- Castor is one of the plants associated in socio-religious ceremonies of many tribes connected with hunting. (Gupta, 1981)
- Leaves are used to rear Eri-silkworms (Hajra and Baishya, 1981).
- Castor oil is being used as lamp oil and the soot obtained by burning lamps with castor oil is used as eyeliner/kajal and bindi purposes.
- Castor oil is used for cooking purposes by majority of the tribal communities

Conclusion

The present investigation reveals that castor still plays a vital role in the health care of the people. In the recent days, the importance of this magnificent crop is diminishing. The benefits of this crop need to be studied scientifically and documented. There is a need to conserve different germplasm and promote the crop.

Table 1 Medicinal uses of castor in different tribes

Plant part used	Ailment
Root	Abortion, Ascites, Asthma, Bronchitis, Carminative, Eructations, Fever, Glands, Hypoglycaemic, Leprosy, Pains, Diseases of rectum, Rheumatism
Seed oil	Amenorrhoea, Aphrodisiac , Anthelmintic, Back pain, Convulsions, Dropsy, Elephantiasis, Heart, Malaria, Purgation, Paralysis, Ringworm, Skin diseases, Tumours
Root bark	Alterative, Purgation, Skin diseases
Flowers	Anal troubles, Glandular tumour, Vaginal pain
Stem	Anticancer,Hypoglycaemic, Antiprotozoa
Leaf	Antiviral, Biliousness, Body swellings, Boils and sores, Burns, Earache, Eyes, Galactagogue, Headache, Malaria, Night blindness
Fruit	Appetiser, Liver diseases, Pains, Piles, Spleen diseases, Tumours

Source: Borthakar, 1981

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Preliminary studies on screening of castor genotypes against grey mold (*Botrytis ricini* Godfrey)

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Abstract

Field screening was carried out at two locations in Tapioca and Castor Research Station, Yethapur, Salem district, Tamil Nadu, during the rainy season of 2009 to find out the resistant source against *Botrytis* grey mold of castor. Among 14 entries of advanced varietal and hybrid trial (AVHT), 12 entries of initial hybrid trial (IHT) and 10 entries of initial varietal trial (IVT) along with local check, 48-1 recorded the grey mold incidence of 9.8 and 9.2% disease index (PDI) on the secondary and tertiary spikes which shows the resistance reaction. Three entries *viz.*, DCS 9, DCH 519 and GCH 7 were recorded less than 25 PDI (ranged from 19.5 to 25.0 PDI on secondary and tertiary spikes) and they showed moderately resistant reaction. 48-1 recorded the grey mold incidence of 8.85 and 8.4 PDI in secondary and tertiary spikes which shows the resistance reaction. Castor variety, DCS 9 recorded 19.1 and 13.5 PDI on the secondary and tertiary spikes which showed moderately resistant reaction (IVT). None of the entry showed resistant reaction however two entries *viz.*, DCH - 519 and GCH - 7 were recorded moderately resistant reaction (less than 25 PDI) in IHT.

Keywords: Castor, screening, *Botrytis* grey mold, resistant, susceptibility

Introduction

India ranks first in the castor (*Ricinus communis* L.) production in the world with an average productivity of 732 kg/ha from an area of 1094 lakh ha. Its cultivation is mainly confined to the states of Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Rajasthan and Orissa. Grey rot caused by *Botrytis ricini* Godfrey is becoming a serious threat to castor cultivation especially in Tamil Nadu, where the crop is devastated during cyclonic and incessant rains. The disease appears at flowering and capsule development stage with the prevalence of continues cyclonic weather in south east coastal regions of India for a few days, which results in humidity build up coupled with low temperature conditions (Raoof and Yasmeen, 2006). *Botrytis* spp. have been reported to develop resistance towards the regularly used fungicides. Chemical control alone is no more a recommendation for the management of *Botrytis* in castor due to development of fungicide resistance. Continuous use of the fungicides for the control of the above disease had forced the workers to find out some alternative method for its management, of which the use of resistant varieties is the ideal one. Therefore the present investigation was under taken to find out the source of resistance to grey mold in castor.

Materials and methods

Field experiments were conducted in randomized block design with three replications during the rainy season of 2009 at two locations *viz.*, pathology trial and breeding trial in Tapioca and Castor Research Station, Yethapur to identify the resistant source against grey mold in castor. Fourteen genotypes of advanced varietal hybrid trial (AVHT), 12 entries of initial hybrid trial (IHT) and 10 entries of initial varietal trial (IVT) were grown in plots with size of single row of 6 m length and a spacing of 90 cm x 60 cm. Ten seeds of each entry were grown. The recommended agronomic practices were followed. The *Botrytis* grey mold incidence was recorded in spike orders by calculating per cent disease index (PDI). Pooled analysis for the two locations was done. Data was statistically analyzed and presented in tables 1, 2 and 3.

Results and discussion

Among 14 entries and one local check screened for *Botrytis* grey mold disease, the variety *viz.*, 48-1 recorded the minimum of 11.8 and 6.7 PDI on the secondary and tertiary spikes when compared to the local check (TMVCH 1) which has recorded the maximum of 39.9 and 34.7 PDI at location 1 (Table 1). At the second location, the minimum grey mold incidence of 7.8 and 11.8 PDI was recorded by 48-1 where as local check recorded the maximum of 52.5 and 34.8 PDI on secondary and tertiary spikes (Table 1).

Pooled analysis of the AVHT revealed that castor variety, 48-1 recorded the grey mold incidence of 9.8 and 9.2 PDI on the secondary and tertiary spikes which shows the resistance reaction. Three entries *viz.*, DCS 9, DCH 519 and GCH 7 were recorded less than 25 PDI (ranged from 19.5 to 25.0 PDI on the secondary and tertiary spikes) and they showed moderately resistant reaction. The other entries and local check recorded susceptible reaction and ranged from 25.1 to 46.2 PDI (Table 1)

Table 1 Screening of *Botrytis* grey mold of castor in advanced varietal and hybrid trial, rainy season, 2009

Genotypes	Botrytis grey mold incidence (PDI)					
	Location 1		Location 2		*Pooled of two locations*	
	Secondary spikes	Tertiary spikes	*Secondary spikes*	Tertiary spikes	Secondary spikes	Tertiary spikes
DCS - 9	9.0	8.0	40.7	40.7	25.0	25.0
48 - 1	11.8	6.7	7.8	11.8	9.8	9.2
MC1-8	34.7	28.8	24.4	34.7	29.5	31.7
JC – 1	28.1	27.3	21.9	28.1	25.0	27.7
DCS – 105	35.5	26.6	40.7	24.2	38.1	25.4
JC – 2	32.4	33.3	38.4	32.5	35.4	32.9
DCS – 106	30.3	25.2	20.0	30.3	25.1	27.7
DSP – 222	27.4	18.9	39.2	34.8	33.3	26.8
DCS – 107	28.1	28.1	25.1	18.5	26.6	23.3
RHC – 199	36.9	35.5	40.7	31.0	38.8	33.2
JHB – 958	30.3	28.8	49.9	31.0	40.1	29.9
DCH – 177	31.0	29.5	34.0	28.8	32.5	29.1
DCH – 519	13.3	17.7	31.0	26.6	22.1	22.1
GCH – 7	19.9	11.8	19.2	37.0	19.5	24.4
TMVCH 1	39.9	34.7	52.5	34.8	46.2	34.7
CD (P=0.05)	16.3	15.6	24.4	12.85	15.0	17.2

Table 2 Screening of *Botrytis* grey *mold* of castor in initial hybrid trial, rainy season, 2009

Genotypes	*Botrytis* grey mold *incidence* (PDI)					
	Location 1		Location 2		*Pooled of two locations*	
	Secondary spikes	*Tertiary spikes*	Secondary spikes	Tertiary spikes	Secondary spikes	Tertiary spikes
DCH – 177	59.3	54.0	32.4	45.0	45.8	49.5
DCH - 519	15.5	20.5	31.8	25.0	23.6	22.7
GCH – 7	15.1	16.2	33.4	24.2	24.2	20.2
PCH – 234	54.7	46.6	34.0	49.6	44.3	48.1
PCH – 244	34.7	37.0	34.8	34.8	34.7	35.9
NBCH – 11662	24.4	27.3	34.4	26.9	29.4	27.1
JHB – 968	41.4	37.7	34.2	39.6	37.8	38.6
RHC – 277	54.0	42.9	35.1	54.3	44.5	48.6
SHB – 864	59.2	46.8	34.8	53.1	47.0	50.9
JHB – 969	65.0	55.5	35.5	57.7	50.	56.6
SHB – 872	67.3	44.3	35.1	59.3	51.2	51.8
SHB - 873	34.7	32.5	34.2	34.5	34.4	33.5
TMVCH 1	72.5	53.3	34.2	57.9	53.3	55.6
CD (P=0.05)	15.8	13.3	11.48	14.45	11.05	17.2

Among 12 entries and one local check *screened* at location 1 under IHT for *Botrytis* grey mold disease, the *entries viz.*, DCH-519 and GCH-7 were recorded *less than 25* PDI (ranged from 15.1 to 20.5 PDI on the secondary and *tertiary spikes*) and showed their reaction of *moderately resistant* when compared to the local check (TMVCH 1) *which recorded the maximum* of 72.5 and 53.3 PDI (*Table 2*). *Whereas, at location* 2, in IHT none of the entry showed resistant *reaction* (Table 2)

Pooled analysis of IHT showed that none of the entry showed resistant reaction however two entries *viz.*, DCH-519 and GCH-7 were recorded moderately *resistant reaction* (less than 25 PDI) where as local check recorded 53.3 and 55.6 PDI on the secondary and tertiary spikes. (*Table 2*).

Among 10 entries screened at location 1 under IVT for resistance *against Botrytis grey mold*, 48-1 recorded the grey mold *incidence of 6.7and 4.7 PDI* on the secondary and tertiary spikes *which shows the resistance* reaction. Two entries *viz.*, DCS-9 and *JI 368 were recorded* less than 25 PDI (ranged from 19.5 to *25.0 PDI on the secondary* and tertiary spikes) and they showed *moderately resistant* reaction. The other entries as well as *local check recorded* susceptible reaction and ranged from *32.9* to *74.7 PDI (Table 3)*. However, at location 2 none of the entry *showed resistant reaction*, however three entries *viz.*, 48-1, *DCS 9 and JI 368 recoded* ranged from 11.0 to 25.0 (showed *moderately resistant*) (*Table 3*).

Table 3 Screening of *Botrytis* grey mold of castor in initial varietal trial, rainy season, 2009

Genotypes	*Botrytis* grey mold incidence (PDI)					
	Location 1		Location 2		Pooled of two locations	
	Secondary spikes	Tertiary spikes	Secondary spikes	Tertiary spikes	Secondary spikes	Tertiary spikes
48 – 1	6.7	4.7	11.0	12.1	8.85	8.4
DCS – 9	19.0	12.0	19.2	15.1	19.1	13.5
SKI – 332	59.9	44.7	46.6	59.9	53.2	52.3
SKI – 338	73.9	63.6	27.9	63.9	52.6	63.7
JI – 368	20.3	20.6	24.7	25.0	22.5	22.9
MCI – 9	74.5	39.2	37.7	64.8	56.1	52.0
JC – 8	62.1	43.6	68.0	55.5	65.0	49.5
MCI – 10	74.7	69.5	23.7	64.8	49.2	67.1
JC – 10	64.3	56.2	22.9	54.3	43.6	55.2
JC - 12	50.3	42.9	45.1	50.3	47.7	46.6
TMV 6	52.5	51.0	32.5	52.5	42.5	51.7
CD (P=0.05)	27.1	31.3	14.94	16.56	22.1	25.2

Pooled analysis of the IVT showed that castor variety, 48-1 recorded the grey mold incidence of 8.85 and 8.4 PDI on the secondary and tertiary spikes which shows the resistance reaction. DCS - 9 recorded 19.1 and 13.5 PDI on the secondary and tertiary spikes which showed moderately resistant reaction. The other entries as well as local check recorded susceptible reaction and ranged from 22.5 to 67.1 PDI (Table 3).

In the present investigation, the result revealed that the variety *viz.*, 48-1 recorded lowest disease incidence. Similarly, Orellana and Thomas (1963) reported cultivars of castor with spiny capsules borne in compact racemes to be more susceptible to grey mold than spineless capsules in open raceme type. Raoof and Yasmeen (2006) also reported spineless castor variety 48-1 to be less susceptible. Janila *et al.* (2009) identified an advanced breeding line PCS-170 showed field tolerance to *Botrytis* grey mold due to the presence of scaly leaves. Among 423 germplasm entries screened for resistance against *Botrytis* grey mold under artificial epiphytic conditions in the field, 28 entries exhibited tolerant reaction.(<10% capsule infection) and three entries were disease free under artificial inoculation conditions under green house conditions (Anonymous, 2009).

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A bibliometric study of castor research in India (1985-2009)

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Abstract

Bibliometric analysis of Crop CD database is done for the last 25 years (1985-2009) on castor crop. Different parameters *viz.*, five year wise distribution pattern, distribution among castor crop and subject wise distribution are considered for the analysis. It was observed that during 1985-1990 highest number of articles on castor were published and the lowest number were in the period between 1995-2000. Although there was increase in the number of articles after 2000 the rate of increase was slow. The articles published with respect to India are 746 which are about 22 % of overall articles published. Though globally the articles published is low during 1996-2000, India contributed highest, i.e., nearly 35% of articles. In India highest number of articles (230) are from Andhra

Pradesh followed by Gujarat (146) and Tamil Nadu (99). Among the different disciplines the number of publications were highest in physiology followed by entomology and plant breeding.

Keywords: Bibliometric analysis, Journal of Oilseeds Research, Crop CD databases

Introduction

Bibliometrics has become a standard tool of science policy and research management in the past decades. All significant compilations of science indicators, to a large extent rely on publication and citation statistics and other bibliometric techniques. Studies of publication patterns, also known as bibliometric or quantitative studies are useful indicators of scientific productivity, trends, emphasis of research in various disciplines It has practical applications in measuring the coverage and quality of Journals. It also helps in library resource management and planning strategies for documentation services to the user community (Hazrika *et al.*, 2003) and of researchers' preferences for publication outputs. Results of such studies may be very useful in decision making in research administration and planning, in collection development and use in libraries (Basappa *et al*, 2009).

Many extensive bibliometric studies of important science fields have appeared during the last three decades. The aim of these studies were to measure national research performance in the international context or to describe the development of a science field with the help of bibliometrics. In the present study, an attempt has been made to analyze the status of research articles related to castor with special reference to India. Similar studies in literature were carried out by Balog (1980) in agriculture research and publications, with particular reference to oilseed research (Damodaram and Rajsheker, 1995) in growth and collaboration trends, (Kalyane and Sen, 1995). Bibliometric study of JOR and productometric study of scientists of ICAR's National Research Centre for Soybean was studied by Kumar and Kumar (2004). Recently in 2008 collaboration in research productivity in oilseeds research institutes of India was studied by Kumar and Kumar (2008).

Materials and methods

The castor related articles published in various journals cited by Commonwealth Agricultural Bureaux Abstracts during 1985-2009 year-wise, state-wise and discipline-wise were extracted and their distribution pattern studied.

Results and discussion

The total number of articles published in castor across disciplines for the last 25 years was 3430. For this study, data from 285 journals published world wide were considered. The distribution pattern of articles presented over a block of five years are presented (Fig. 1). It was observed that during 1985-1990 highest number of articles on castor were published and the lowest number were in the period between 1995-2000. Although there was an increase in the number of articles after 2000 the rate of increase was slow.

The articles published with respect to India are 779 which are about 22% of overall articles published. No particular trend was observed in the distribution of articles. An interesting observation is that even though globally the articles published is low during 1996-2000, India contributed highest, *i.e.*, nearly 35% of the articles. A state-wise analysis indicated that from Andhra Pradesh highest number of articles i.e. 230 on castor were published followed by Gujarat (146) and Tamil Nadu (99) (Table 1). Five yearly distribution pattern of articles among states indicated that over the years the publication of articles has decreased. Even though highest number of articles from Andhra Pradesh were published there was nearly 50% reduction during 2006-09 compared to 1985-90. Similar trend was observed in the other states also. This requires attention of research administration and policy planners.

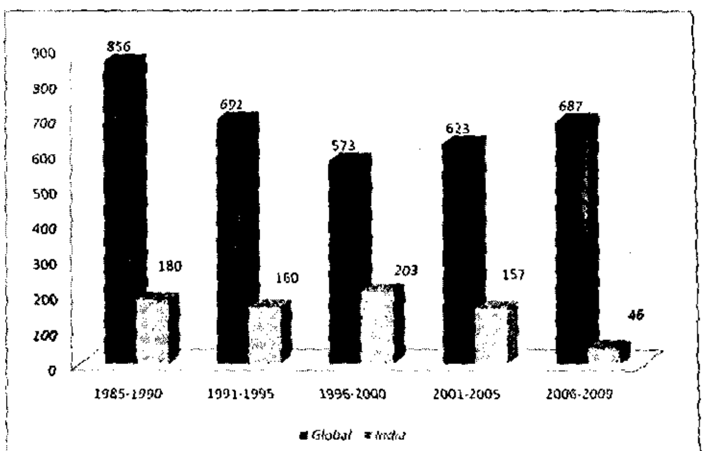

Fig. 1. Total number of research papers published on castor

Table 1 statewise contribution of articles (1985-2009)

State	1985-90	1991-95	1996-2000	2001-05	2006-09	Total
Andhra Pradesh	53	48	51	52	26	230
Arunachal Pradesh	1	--	--	4	1	6
Assam	3	8	5	4	--	20
Bihar	2	6	4	1	1	14
Goa	1	--	--	--	--	1
Gujarat	45	21	50	26	4	146
Haryana	9	10	7	3	2	31
Himachal Pradesh	--	3	2	1	--	6
Jammu and Kashmir	--	--	1	--	--	1
Karnataka	10	8	--	14	2	34
Kerala	4	3	3	--	--	10
Madhya Pradesh	4	6	4	6	--	20
Maharashtra	10	4	13	8	3	38
Manipur	3	2	5	1	--	11
Meghalaya	1	--	--	3	--	4
Mizoram	--	--	--	--	--	0
Nagaland	1	1	--	--	--	2
Orissa	5	3	7	--	2	17
Punjab	15	8	3	2	--	28
Rajasthan	--	9	7	19	--	35
Sikkim	1	--	2	--	--	3
Tamil Nadu	18	24	38	12	7	99
Tripura	1	--	--	--	--	1
Uttar Pradesh	--	6	4	--	--	10
West Bengal	3	6	5	4	--	18
Total	190	170	211	160	48	779

Among the different disciplines the number of publications were highest in physiology followed by entomology and plant breeding. Discipline-wise five yearly distribution of articles also indicated that there was a decrease in number of publications over the years (Table 2). Apart from the major disciplines mentioned above there are 338 research articles on the other allied sectors involved in castor research. The Fig. 2 shows distribution pattern of various major sectors for the last 25 years.

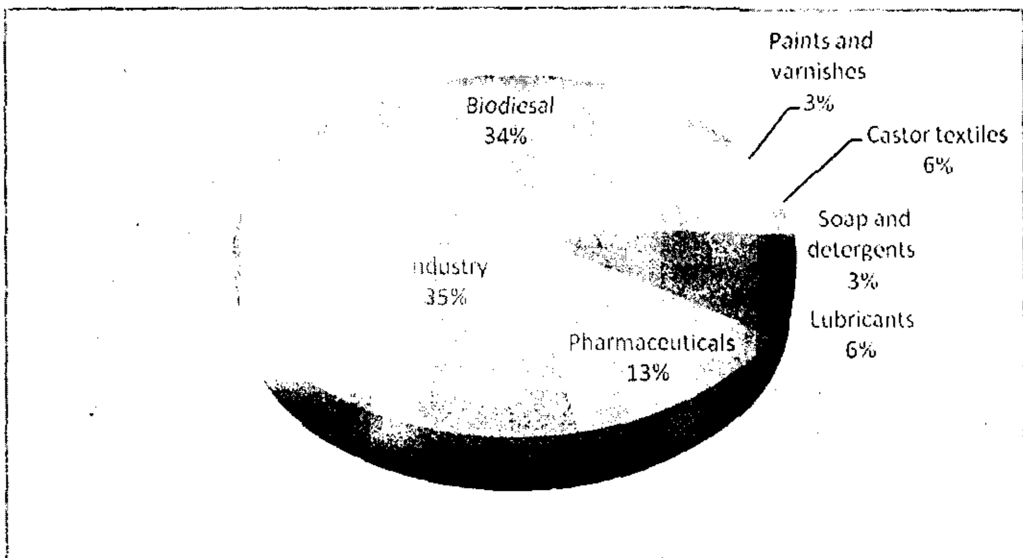

Fig. 2. Distribution pattern of castor research in allied sectors

Table 2 Disciplinewise distribution of articles

Discipline	1985-90	1991-95	1996-2000	2001-05	2006-09	Total
Biotechnology	38	27	63	19	17	164
Breeding	143	53	151	35	102	484
Agronomy	29	16	25	23	32	199
Soil science	6	17	14	10	2	49
Physiology	214	58	125	129	93	619
Pathology	43	34	52	26	16	171
Entomology	235	61	177	70	49	592
Nematology	59	27	65	26	13	190
Social sciences	21	11	28	23	43	139

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Evaluation of different castor genotypes in terms of yield parameters and fecundity in eri silkworm

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Abstract

Out of 40 castor genotypes RG-902, RG-2094,,RG-1965 and RG-2095 from DOR Hyderabad were the best genotypes, which supported good growth and development of eri-silkworm compared to the check variety Aruna. Further, these genotypes were superior over the best genotypes *viz.*, RG-356, RG-323 and SKI-80 from RARS, Raichur. Out of top seven genotypes, RG-902 an early maturing with double bloom was found to be best suited for commercial rearing and seed cocoon production of eri silkworm, which has not only increased economic cocoon traits but also significantly increased the fecundity of eri silkworms. This genotype was closely followed by RG-2094, RG-1965 andRG-2095. Therefore, the castor genotype RG-902 can be utilized to increase eri cocoon and egg production.

Keywords: Eri silkworm, cocoon, fecundity, effective rate of rearing (ERR), castor genotypes

Introduction

Castor is one of the non-edible oilseed crops cultivated mainly in marginal lands under rainfed conditions. The leaves of this plant are used to feed goat and eri silkworms But the leaves are commercially exploited for eri silkworm rearing which produces Ahimsha silk of commerce. There are number of castor genotype available with different Research Institutions. Therefore, the present studies were undertaken to find out the better genotypes for eri silkworm rearing.

Materials and methods

An experiment on the performance of castor genotypes for eri culture was carried out during September- October 1998 at DBT, Eri culture laboratory, UAS, Dharwad. Forty castor genotypes collected from DOR Hyderabad were evaluated by feeding the leaves of each genotype separately to eri silk worms from hatching till cocoon spinning (Table 1). The best genotypes from DOR Hyderabad *viz.*, RG-902, RG-2094, RG-1965 and RG-2095 were compared with best castor genotypes RG-35, RG-323, SKI-80 of Raichur for eri culture.

Results and discussion

Out of 40 castor genotypes early maturing double bloom genotype RG-902 recorded significantly higher gain in larval weight, economic traits of cocoon and fecundity as compared to other genotypes. The genotype RG-902 recorded significantly higher larval weight (77.12 g/10) cocoon weight (39.02 g/10), shell weight (5.0 g/10) pupal weight (33.50 g/10), shell ratio (12.84 %), ERR (86.0 %) and fecundity (395.33 / female) followed by RG-2904, RG-1965 and RG-2095. Where as, these parameters were least in RG-443 (72.97 g, 35.55g, 4.107g, 30.93g, 11.55%, 78.50% and 328.33 eggs/female, respectively). Further, seven genotypes *viz.*, RG-445, RG-453, RG-447, RG-911, RG-904, RG-793 and RG-443 performed poor compared to local cultivar Aruna. Among the genotypes evaluated RG-443 was least preferred by the eri silkworm. Out of 25 castor genotypes from RARS, Raichur evaluated, Patil *et al.* (2000) reported that RG-356, RG-323 and SKI-80 were best over check variety Aruna for eri culture.

Among the top seven genotypes evaluated further for cocoon yield parameters and fecundity of eri silkworm, the genotype RG-902 found significantly superior over other genotypes in recording higher larval weight, cocoon weight, shell weight, pupal weight, shell ratio, ERR and fecundity followed by RG-2094. Whereas, these parameters in all other selected genotypes were significantly superior over standard check, Aruna (Table 2). Among the genotypes evaluated, the genotype RG-902, an early maturing, double bloom castor genotype found best suited for commercial rearing and seed cocoon production of eri silkworm, which has not only increased economic traits but also significantly increased the fecundity of eri silkworm. This genotype was closely followed by RG-2094, RG-1965 and RG-2095.

Table 1 Comparison of better castor genotypes of RARS, Raichur and DOR, Hyderabad in terms of yield parameters and fecundity in eri silk worm

Genotypes	Larval weight (g/10)	Cocoon weight (g/10)	Shell weight (g/10)	Pupal weight (g/10)	Shell ratio	ERR	Fecundity
RG-902	77.12 [a]	38.96 [a]	4.99 [a]	33.45 [a]	12.80 [a]	85.81 [a]	397.66 [a]
RG-2094	76.52 [e]	38.75 [b]	4.93 [b]	33.31 [b]	12.72 [b]	85.03 [c]	390.66 [b]
RG-1965	76.46 [f]	38.62 [c]	4.88 [c]	33.21 [g]	12.64 [c]	85.26 [b]	382.00 [c]
RG-2095	76.04 [g]	38.42 [d]	4.84 [d]	33.07 [f]	12.60 [d]	83.87 [f]	367.66 [de]
RG-355	76.63 [d]	37.84 [g]	4.35 [g]	33.11 [e]	11.46 [g]	84.29 [e]	362.00 [e]
RG-323	76.90 [b]	38.16 [e]	4.43 [e]	33.24 [c]	11.61 [e]	85.00 [c]	371.66 [d]
SK-I-80	76.66 [c]	38.05 [f]	4.37 [f]	33.16 [d]	11.49 [f]	84.61 [d]	369.00 [d]
Aruna (check)	73.71 [h]	37.27 [h]	4.15 [h]	32.49 [h]	11.16 [h]	82.11 [g]	348.00 [f]
CD (P=0.05)	0.05	0.14	0.04	0.02	0.02	0.59	10.04
SEm±	0.02	0.05	0.01	0.01	0.04	0.19	3.31

Means followed by the same alphabet do not differ significantly by DMRT at P=0.05

Table 2 List of castor genotypes from DOR, Hyderabad used for the study

Accessions	Character
RG-904, RG-1922, RG-1932, RG-1934, RG-1942	Green stem, No blooms
RG-793, RG-447, RG-442, RG-445, RG-424, RG-425, RG-453	Green stem, Single bloom
RG-443, RG-444, RG-446, RG-452, RG-902	Green stem, Double bloom
RG-908, RG-909, RG-1941, RG-1939	Red stem, Single bloom
RG-910, RG-911, RG-914, RG-915	Red stem, Double bloom
RG-899, RG-896, RG-912,RG-1965	Red stem, Triple bloom
RG-806, RG-862, RG-907, RG-917	Red stem, No blooms
RG-2092, RG-2094, RG-2095	Late mauring ((>150 days)
RG-1988, RG-1990, RG-1997, RG-2013, RG-2019, RG-2021	Very late maturing (>200 days)

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Castor as a trap crop in the integrated pest management in groundnut

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Abstract

Experiments were conducted during the rainy season of 2008 and 2009 at Oilseeds Research Station, Latur, Maharashtra. *Spodoptera litura* is the major defoliator on groundnut. Castor was used as trap crop in the integrated pest management (IPM) of groundnut. The experiment was laid out in a pair plot technique design with two treatments and sixteen replications to study the effect of castor as a trap crop in the IPM of groundnut. The diversity created by introducing castor as trap crop in IPM of groundnut resulted in buildup of natural enemies (*Coccinellids* and Spiders) of the pests. As a result of the increased population of natural enemies, pest incidence was kept below economic threshold level in IPM. Damage on groundnut by insects pests was low in IPM compared to non IPM plot.

Keywords: Castor, trap cropping, *Spodoptera*, groundnut

Introduction

Intercropping is one of the important cultural practices in pest management and is based on the principle of reducing major insects pest by increasing the diversity of an ecosystem (Risch, 2005). Trap crops are plant stand that are grown to attract insects or other organisms so that the target crop escapes pest attack. Protection is achieved either by preventing the pests from reaching the crop or by concentrating them in certain part of field where they can be easily destroyed. Trap cropping has been successfully employed on a large scale in four crop ecosystems *viz*., cotton and soybean in USA, Potatoes in Bulgaria and Cauliflower in Finland. In Asian countries, trap cropping has proved successful in experimental studies in a number of crops and has been recommended for large scale utilization (Simwat, 1994). In rice, trap cropping of rice for green leaf hopper control resulted in 29 % higher economic return than untreated control (Hokkanen, 1991). Planting of castor as trap crop diverts the population of *Spodoptera litura* (Fabricius) from cotton (Dhawan, 1999).

Intercropping and mixed cropping systems are more popular forms of crop diversity practiced in rainfed agriculture. These systems provide situations that are less pest prone compared to the monocultures (Srinivas Rao *et al*., 2002). Several studies indicated that diversification practices such as intercropping in pigeonpea and other crops are beneficial because of reduced pest damage (Songa *et al*., 2007). Keeping in view these considerations, attempt has been made to examine how the incidence of insects pest differ in IPM in groundnut with castor as trap crop compared to sole crop of groundnut.

Materials and methods

Experiments was laid out in pair plot technique within two treatments *viz*., T_1- IPM in groundnut with castor as trap crop and T_2- Sole crop conducted at Oilseeds Research Station, Latur. IPM module with castor consists of deep ploughing in summer, sowing of castor crop as trap crop for defoliators, installation of pheromone traps @ 10/ha for monitoring and mass trapping of *S. litura*, leaf miner and *Helicoverpa*, collection and destruction of egg masses and early instars larvae from castor crop, application of NSKE 5% at 20 and 30 DAS and application of *HaNPV* and *SlNPV* 250 LE/ha. Observations on sucking pests, defoliators and leaf miner were recorded from five randomly selected plants from each plot of the replication and pod yield was recorded at harvest.

Results and discussion

Perusal of data (Table 1 and 2) revealed that the population of sucking pest, leaf miner and defoliator was kept below economic threshold level in IPM compared to farmers practice. Suppression of pests of groundnut due to the application of neem pesticide, installation of pheromone traps and application of NPV bio-pesticides was well documented. Average mean value of defoliator larvae / plant was 0.18 in IPM and 2.34 larvae/plant in farmers practice. The average mean value of leaf miner larvae in IPM was 0.32 and 5.54 in farmers practice. The average thrips and jassids population was 0.37 and 1.76/3leaves in IPM and 5.25 and 5.75 / 3 leaves in farmers practice, respectively. The pod yield in the IPM module was 1612 kg/ha, whereas it was 1088 kg/ha in farmers practice. There was 32.5 % significant reduction of the seed yield in the farmers practice compared to IPM module. Thus, present study suggests IPM module with castor as a trap crop was found least number of populations of defoliators, leaf miners and sucking pests and recorded highest yield.

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Table 1 IPM module with castor as trap crop compared with farmers' practice

IPM module					Farmers' practice				
Av. defoliators larvae/plant	Av. leaf-miner larvae/plant	Av. thrips/ 3 leaves	Av. jassids/ 3 leaves	Yield (kg/ha)	Av. defoliators larvae /plant	Av. leaf miner larvae/plant	Av. thrips/ 3 leaves	Av. jassids/ 3 leaves	Yield (kg/ha)
0.20	0.40	0.2	2.00	1645	2.00	5.0	3.00	6.00	1112
0.10	0.60	0.2	1.80	1632	1.80	6.0	4.00	5.00	1101
0.20	0.20	0.4	2.00	1635	2.00	7.0	5.00	5.00	1146
0.20	0.30	0.6	2.20	1613	3.00	6.5	6.00	4.00	1116
0.10	0.20	0.2	1.00	1626	2.00	7.2	7.00	6.00	1089
0.20	0.10	0.4	2.20	1537	2.00	7.0	6.00	6.00	1087
0.20	0.20	0.5	2.00	1636	2.00	8.0	5.00	7.00	1123
0.10	0.30	0.6	2.00	1622	2.50	6.0	5.00	7.00	1090
0.30	0.10	0.4	2.00	1635	2.60	5.0	4.00	6.00	1087
0.10	0.30	0.2	1.50	1612	3.00	5.0	4.00	6.00	1123
0.20	0.40	0.6	2.00	1614	2.20	4.0	5.00	7.00	1078
0.30	0.40	0.4	1.50	1548	2.60	5.0	4.00	5.00	992
0.20	0.40	0.4	2.00	1624	2.40	4.0	5.00	5.00	1035
0.20	0.20	0.2	1.00	1550	2.60	5.0	6.00	6.00	1059
0.10	0.40	0.3	1.00	1635	2.60	4.0	7.00	6.00	1078
0.20	0.60	0.4	1.00	1614	3.00	4.0	8.00	5.00	1092
0.18	**0.32**	**0.37**	**1.76**	**1612**	**2.34**	**5.54**	**5.25**	**5.75**	**1088**

Average values are given in bold

Table 2 IPM module compared with farmers' practice

Treatments	Av. Spodoptera/plant	Av. leaf miner /plant	Av.thrips/3 leaves/plant	Av. jassids / 3 leaves	Av. yield (kg/ha)	Increase in yield (kg/ha)
IPM	0.18	0.32	0.37	1.76	1612	32.50 %
Farmers' practice	2.34	5.54	5.25	5.75	1088	
T value (P=0.05)	22.1 (4.75)*	15.10 (3.94)*	14.63 (3.88)*	16.80 (4.15)*	52.24 (7.26)*	

* Significant at 5%

Economic analysis of different phosphorus levels on castor based intercropping system

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Abstract

A field experiment was conducted to find out profitable castor based inter cropping system for sustainable seed yield under different doses of phosphorus at College of Agriculture, Latur. The experimental findings revealed that intercropping of castor + coriander and application of 90 kg P_2O_5/ha recorded significantly higher yield attributes as well as gross and net monetary returns as compared to rest of the intercropping systems.

Keywords: Castor, economic analysis, phosphorus levels, intercropping

Introduction

Intercropping is one of the best methods for increasing production under present circumstances. Today, *per capita* availability of food grain/year is 225 kg and population is increasing very fast, so to meet the food grain requirement of increasing population, we must adopt intercropping system to utilize available land and resources efficiently, for more production of food grains (Anonymous, 2006). To utilize the natural resources in better way resulting in higher production/unit area, it is become essential to involve two or more crops having different growth habits. Phosphorus (P) is an important nutrient for all the crops in general and leguminous crop in particular. The most obvious effect of P is on roots. Phosphorus is also needed by nodule bacteria which affect the nitrogen fixation in leguminous crops (Arya and Karla, 1988). India is the principle producer of castor, has an area of 739 thousand ha and produces 793 thousand t. having productivity of 1073 kg/ha (Anonymous, 2006). Therefore present attempt was made to find out profitable castor based intercropping system for sustainable yield under different doses of P.

Materials and methods

A field experiment was laid out in factorial randomized block design with three replications. Twenty treatments were formed by five combinations of intercropping and four levels of P. The layout consisted of 60 experimental units in three replication *viz.*, sole crop, castor + soybean (1:2), castor + coriander (1:3), castor + black gram (1:3) and castor + green gram (1:2) with four P levels *viz.* 0,30,60 and 90 kg P_2O_5/ha. Cost of cultivation was calculated by considering the total cost required during the cultivation of main crop and intercrop. The gross income was calculated by summation of main produce and by produce of main crop and intercrop, then finally net monetary returns was calculated. Analysis of variance for factorial experiment was done.

Results and discussion

The data on castor equivalent yield (kg/ha) as influenced by intercropping systems and P levels revealed that mean castor equivalent yield was significantly influenced (Table 1). Among the different intercropping systems, castor + coriander recorded significantly higher castor grain equivalent as compared to other intercropping systems. The second highest castor equivalent yield was observed in castor + green gram intercropping system and it was significantly superior over rest of the systems.

The significant effect of different P levels was observed in castor equivalent yield. Application of 90 kg P_2O_5/ha recorded significantly higher castor grain equivalent yield as compared to application of 30 kg P_2O_5/ha and control, however it was found at par with the application of 60 kg P_2O_5/ha Interaction effect of intercropping and P level was found to be non-significant.

Table 1 Mean cost of cultivation (₹/ha), gross monetary returns (₹/ha) and net monetary returns (₹/ha) as influenced by different intercropping and phosphorus treatments

Treatments	Castor equivalent yield (kg/ha)	Gross monetary return (₹/ha)	Cost of cultivation (₹/ha)	Net monetary return (₹/ha)
Intercropping system				
Sole castor	1403	30860	11257	19604
Castor + soybean	1957	43027	15087	27970
Castor + coriander	2514	55312	14237	41075
Castor + blackgram)	1899	41786	12392	29394
Castor + greengram)	2171	47754	--	35420
SEm +	59	558	--	687
CD (P=0.05)	165	1543		1901
Phosphorus level (kg P_2O_5/ha)				
0	1579	34754	11954	22800
30	1849	40688	12690	27998
60	2228	49004	13431	35573
90	22998	50569	--	36399
SEm +	53	548	--	614
CD (P = 0.05)	148	1580		1700
Interaction (C x P)				
SEm±	119	1115	--	1374
CD (P=0.05)	NS	NS	--	NS
Grand mean	1989	43754	13061	30693

Rate of produce (at the time of study): 1) Castor ₹ 2000/q; 2) Soybean ₹ 2200/q; 3) Coriander ₹. 4000/q; 4) Blackgram ₹ 3200/q

Economics: The data on mean gross and net monetary returns (₹/ha) as influenced by different treatments are presented in table 1. The grand mean gross and net monetary returns were ₹ 43754 and 30693/ha, respectively.

Data presented in table 1 revealed that the gross and net monetary returns influenced significantly due to various intercropping systems. Among the intercropping systems, castor + coriander recorded significantly higher gross and net monetary returns. It was followed by castor + green gram intercropping system which had recorded significantly higher gross and net monetary returns as compared to others whereas lowest value for the same were recorded with sole crop castor. These results were in conformity with those of Gangasaran and Gajendra Giri (1983), Jain (1970) and Al-Bakry and Saran (1985). The mean gross and net monetary returns were influenced significantly due to various P levels. Application of 90 kg P_2O_5/ha recorded significantly highest gross and monetary returns as compared to application of 30 kg P_2O_5/ha and control. However, it was at par with application of 60 kg P_2O_5/ha. The mean gross and net monetary returns were not influenced significantly due to interaction of intercropping and P levels. Similar results were also reported by Subbareddy and Venkateswarlu (1989) and Subhash Kumar (2002).

Present results showed that all the intercropping treatments were profitable than sole crop. Intercropping of coriander in two rows in castor was most profitable as compared to other systems. Also, intercropping of two rows of green gram and black gram were also equally profitable. These intercropping treatments fetched 49, 39 and 47% higher profit than sole castor crop.

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Population outbreak of castor semilooper (*Achaea janata* Linn.) and its management

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Abstract

Studies were carried out on an outbreak of castor semilooper, *Achaea janata* Linn. population and its management in the traditional castor growing areas of Ranga Reddy district, Andhra Pradesh. During a population outbreak at Debbadguda and Kandkur villages the defoliation ranged from 25 to 50% with a mean of 40% and 35 to 60% with a mean of 45% due to occurrence of semilooper population ranging from eight to 33 with a mean of 22.6 and 15 to 44 with a mean of 33.2/plant, respectively. Self-sown castor, *Euphorbia hirta*, *E.janiculata*, *E. prostrata Cardiospermum helicacabum*, *Phyllanthus reticulates* weeds, ber and rose served as the alternate hosts. Hands picking of grown up larvae and application of fenvalerate (0.1ml/l) followed by commercial neem 2ml/l, were effective during outbreak conditions and larval parasitoid, *Microplitis maculipennis* Szepligate and insectivorous predatory birds kept population below economic threshold level (ETL) at the later stage. Application of quinolphos (2ml/l) followed by monocrotophos (1.5ml/l) were able to reduce semilooper population but they were toxic to parasitoids. At DOR, Narkoda Farm defoliation ranged from 80 to 100% with a mean of 90% due to occurrence of maximum semilooper population ranging from 30 to 280 with a mean of 78/plant. Application of quinolphos (8ml/l) followed by monocrotophos (6ml/l) using tractor mounted low volume sprayer and hand picking and destruction of grown up larvae was found effective in reducing population below ETL

Keywords: Castor semilooper, population outbreak, management

Introduction

Castor (*Ricinus communis* L.) is an important industrial oilseed crop cultivated throughout the world for oil production. India is the major producer of a castor, with higher productivity levels (1352kg/ha) than world average and dominates the international castor oil trade (DOR, 2010). In India, except Gujarat and Rajasthan the productivity levels of the castor are low in other states due to abiotic and biotic constraints. Among biotic constraints, insect pests dominate the scenario. Castor semilooper, *Achaea janata* Linn. a major defoliator, is considered as the key pest of castor in the rainfed castor belts of Andhra Pradesh. It is also known to occur regularly throughout the country wherever the crop is grown and it has got wide host range. Defoliation in the early stage restricts the growth of the plant and in the later stage affects the growth and development of capsules and seeds. During a severe outbreak 100% yield reduction occurs. Apart from the main host it has been found to feed on more than 79 plant species which includes common weeds, horticultural and agricultural crops and forest plant species. Castor semilooper is one of the polyphagous pests which has high damage potential. An outbreak of the pest will lead to enormous loss to several agricultural and horticultural crops within a span of short period. Castor semilooper is attacked by an array of parasitoids, predators and pathogens during various stages of its development. Keeping in view the nature of outbreak and damage potential of the pest, the present investigations of castor semilooper and its management were studied.

Materials and methods

As a part of National agricultural technology project (NATP on "Development of IPM Modules for Oilseeds and nutritious Cereals-based Production system (ROPS-8)" studies were carried out on population outbreak of castor semilooper and its management in the farmers' castor fields of Debbadguda and Kandkur village in the traditional castor growing areas under Maheswaram watershed of Ranga Reddy district, Andhra Pradesh during 2001-2002, 2002-2003 and 2003-04. Observations were also recorded on the outbreak of semilooper in the DOR, Narkoda Farm during 2010. Details on alternate host plants supporting castor semilooper population during the outbreak, semilooper population/plant, extent of damage, insecticides used for its management and natural enemies associated with the pest were recorded regularly whenever there were outbreaks of castor semilooper population in the castor fields was noticed. Details of various management options used in the management of castor semilooper are given in table 1.

Results and discussion

Observations recorded on alternate host plants supporting castor semilooper population during outbreak, semilooper population/plant, extent of damage, insecticides used for its management during 2001, 2003 in farmers' castor fields of Debbadguda and Kandkur villages and DOR, Narkoda Farm during 2010 is given in table1. A population outbreak of castor semilooper was noticed at both Debbadguda and Kandkur villages during 2001 and Debbadguda alone in 2003. During 2001 population outbreaks at Debbadguda and Kandkur villages the defoliation ranged from 25 to 50% with a mean of 40% and 35 to 60% with a mean of45% due to the occurrence of semilooper population ranging from eight to 33 with a mean of 22.6 and 15 to 44 with a mean of 33.2/plant, respectively. Self-sown castor, *Euphorbia hirta*, *E.janiculata*, *E. prostrata* *Cardiopspermum helicacabum*, *Phyllanthus reticulates* weeds, ber and rose served as the alternate hosts recorded at Debbadguda during 2001 and 2003. Self-sown castor, tamarin, subabul, *E. hirta*, *E. hypersifolia*, *E. prosfrata*, *E. ganiculata*, *Sonchus oleraceus*, *Bauhinia* sp. and *Luctuca runcinata* served as the alternate hosts recorded at Kandkur during 2001. Application of quinolphos (2ml/l) followed by monocrotophos (1.5ml/l) were able to reduce semilooper population but they were toxic to parasitoids. Castor semilooper population was reduced below economic threshold level (ETL) (<4-5 larvae/plant) by hand picking of grown up larvae and applying fenvalerate (0.1ml/l) followed by commercial neem (2 ml/l) formulation initially during outbreak conditions and later stages by larval parasitoid, *Microplitis maculipennis* Szepligate and insectivorous predatory birds like Indian mynah and black drongo at Debbadguda during both the years. Owing to the application of plant origin bio pesticide parasitisation by larval parasitoid was maximum (72%) at Debbadguda compared to Kandkur field (33%) where toxic insecticides were used. Similar observations were recorded by Basappa and Lingappa (2002a; 2002b; 2004a and 2004b).

During a population outbreak, larvae consumed most of the foliage leaving just the veins and petioles causing defoliation ranging from 80 to 100% with a mean of 90% at DOR, Narkoda Farm due to occurrence of maximum semilooper population ranging from 30 to 280 with a mean of 78/plant. Self-sown castor, *E. hirta*, *E. hypersifolia*, *E. prosfrata*, *E. ganiculata* served as the alternate hosts for its perpetuation and population outbreak. Application of quinolphos (8 ml/l) followed by monocrotophos (6 ml/l) using a tractor mounted low volume sprayer and hand picking and destruction of grown up larvae was found effective in reducing population below ETL.

Castor semi looper population in all the stages of growth occurred in the first week of June, July and August and due to which the pest outbreak will be common in August, September and October but the activity will decrease from November on wards. First broods of castor semilooper population might have survived on different alternate hosts before population outbreaks on main crops. Survival of castor semilooper on a perennial castor as reported by Khan (1946) is in conformity with present findings as the pest survived on a perennial castor initially. Later on some field crops, horticultural crops, several weed hosts and a self-sown crop of the castor served as alternate hosts for survival in the off-season (Basappa and Lingappa, 2001).

Castor semilooper is treated as serious pest of several economically important crops and forest trees. In its adult stage, the moth sucks the sap and damage fruits of pomegranate, banana, citrus, guava, orange and mango. Thus, it is one of the polyphagous and uncommon pests whose larvae as well as the adults have become pests of economic importance (Basappa, 1995). Hence in depth knowledge on the pest, its natural enemies, alternate hosts, weather parameters which help in the population outbreak of castor semilooper, effective and eco friendly pest management approaches are essential for sustainable production of the castor.

Table 1 Population outbreak of castor semilooper and its management

Name of the place	Month and Year	Cultivar and crop stage	Larvae/plant (mean)	Defoliation (mean %)	Management options
Debbadaguda	August first week, 2001	GCH-4 50 days old crop	8-33 (22.6)	25-50 (40%)	Fenvalerate 0.1ml/l followed by commercial neem1500 PPM 2ml/l Hand picking of grown up larvae
Kandakur	August first week, 2001	DCS-9 55 days old crop	15-44 (33.2)	35-60 (45%)	Quinolphos 2ml/l followed by monocrotophos 1.5ml/l
Debbadaguda	August first week, 2003	DCS-9 45 days old crop	10-24 (16.2)	20-40 (35%)	Fenvalerate 0.1ml/l followed by commercial neem1500 PPM 2ml/l Hand picking of grown up larvae
DOR, Narkoda Farm	August first week, 2010	Breeding material One year old	30-280 (78)	80-100 (90%)	Quinolphos 8ml/l followed by monocrotophos 6ml/l *(tractor mounted low volume sprayer)* Hand picking of grown up larvae

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Effectiveness of farmer field school (FFS) on knowledge gain and retention by tribal farmers about the castor integrated pest management (IPM) practices

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Abstract

Farmer field school (FFS) on integrated pest management (IPM) practices of castor under participatory seed production programme of Directorate of Oilseeds Research (DOR), Hyderabad were organized during May 2000, among tribal farmers' of Narlakunta thanda (tribal village) of Amangal mandal in Mahaboobnagar district of Andhra Pradesh toward major insect pests, their natural enemies, major diseases and IPM practices. Analysis on pre and post exposure knowledge level of the tribal farmers revealed that the mean knowledge gain of the respondents was 79% with respect to IPM practices on the castor and that contributes to the effectiveness of training through FFS. Evaluation of knowledge retention of the framers toward IPM practices during the subsequent three years revealed that training programmes through FFS are to be imparted once after every two years to keep the respondents remembered and updated about IPM practices on the castor.

Keywords: Castor, IPM, FFS, knowledge gain, knowledge retention

Introduction

Castor (*Ricinus communis* L.) is one of the industrially important non-edible oilseed crops cultivated in India. Gujarat, Rajasthan and Andhra Pradesh are the major castor producing states of the country (DOR, 2010). In Andhra Pradesh castor is predominantly grown as a sole crop by resource-poor farmers under rainfed agro-ecosystem of Mahaboobnagar, Ranga Reddy, Nalgonda districts. There are several production constraints like poor quality seeds of varieties and hybrids, low and erratic rainfall, shallow soils with poor fertility and low resource input in the castor, which resulted in low productivity. Insect pests like red hairy caterpillars (*Amsacta albistriga* Walker), castor semilooper (*Achaea janata* Linn), castor shoot and capsule borer, [*Conogathus punctiferalis* (Dichocrosis punctiferalis Guenee)], tobacco caterpillar (*Spodoptera litura* Fabricius), leafhopper (*Empoasca flavescense* Fabricius) and hairy caterpillars (*Spilosoma obliqua* Walker, *Euproctis* spp and *Pericalia ricini* Fabricius) and diseases like seedling blight (*Phytophthora parasitica*), wilt (*Fusarium oxysporum* f. sp. *ricin*) and grey rot (*Botrytis ricini* Godfrey) are the major biological production constraints of greater economic importance to the castor. In a castor ecosystem, several natural enemies exert greater biological resistance in the succession of insect pests of the castor (Basappa, 2003). Owing to severe incidences of major insect pests and diseases as well as lack of sufficient quantity of quality castor seeds in this traditional castor growing area, farmers switch over to other crops. Hence, the Directorate of Oilseeds Research (DOR) initiated farmers' participatory castor seed production programed in a cluster of villages at Amangal mandal of Mahaboobnagar district during 2000-01. Farmers were trained by DOR task force team (TFT) on quality castor seed production including insect pest and disease management (Padmaiah and Ramanjaneyulu, 2003). After conducting an initial survey among tribal farmers from castor growing villages for their knowledge on major insect pests, their natural enemies, major diseases and integrated pest management (IPM), the TFT felt that there is a need for FFS on IPM and studies on gain in the knowledge after imparting such training. The present study, brings out the results of such analysis on knowledge gain of tribal farmers on IPM practices and knowledge retention by them over a period of time, so that suitable FFS training strategies could be suggested.

Materials and methods

Under the farmers' participatory seed production programme of DOR, Hyderabad, a survey was conducted by TFT during May 2000, to assess the pre-training exposure knowledge among tribal farmers' of Narlakunta thanda (Tribal village) of Amangal mandal in Mahaboobnagar district of Andhra Pradesh toward major insect pests, their natural enemies, major diseases and IPM practices. Based on the pre exposure knowledge possessed by the respondents, FFS were organized on the castor IPM aspects as given in table 1 at different critical stages of the crop to educate farmers on major insect pests, diseases and their management options. Post -exposure knowledge evaluation was done immediately after the FFS training to assess the knowledge gained by the respondents and subsequently on first, second and third year after post exposure evaluation without imparting training, to assess the knowledge retention of the respondents. The collected data during the pre and post exposure trainings were tabulated and analyzed using percentage measures.

Table 1 Castor IPM aspects covered during FFS

A	Major insect pests- red hairy caterpillars, castor semilooper, tobacco caterpillar, castor shoot and capsule borers, leafhopper and hairy caterpillars
B	Economic threshold level (ETL) of castor semilooper (4-5 larvae/plant), tobacco caterpillars (10-15% defoliation) and castor shoot and capsule borer (10% capsule damage)
C	Major diseases - seedling blight, root rot, wilt and grey rot
D	Economic threshold levels (ETL) of seedling blight (10%), wilt (15-20%) and grey rot (10%)
E	Natural enemies of major insect pasts Egg parasitoids, (*Trichogramma chilonis* Ishii), larval parasitoids (*Microplitis maculipennis* Zepligate, *Euplectrus maternus* Bhatnagar, *Rhogas* spp., *Apanteles hyposidrae* Wilkin) on castor semilooper, *Charops obtusus* Morley on Bihar hairy caterpillar and castor semilooper and *Cotesia flavipes* (Cameron) on tobacco caterpillar and larval parasitoids of capsule borer. Insect predators, spiders and insectivorous birds.
F	Toxicity of insecticides to natural enemies and their adverse effect in IPM
G	Conservation of natural enemies and their role in IPM
H	Role of crop rotation of the castor with sorghum and summer ploughing in IPM
I	Role of insect and disease resistant varieties or hybrids in IPM
J	Importance of seed treatment in IPM
K	Vegetative trapping and furrow trapping of red hairy caterpillar larvae
L	Use of neem seed kernel extract in IPM
M	Use of bird perches to attract insectivorous birds
N	Hand picking and destruction of early stages gregarious larve of *Spodotpera* and hairy caterpillars
O	Need-based use of recommended insecticides against major insecticides
P	Need-based use of recommended fungicides against major diseases
Q	Commercial bio pesticides of plant and microbial origin and benefits in IPM
R	Removal of affected spikes due to *Botrytis* and application of nitrogen when crop is affected due to cyclonic rains
S	Safety of bio pesticides to natural enemies and beneficial organisms and benefits in IPM

Results and discussion

The mean pre and pose exposure knowledge scores of the respondents were 7.7 and 36.7 respectively and the mean knowledge gain was 29.0 (Table 2). The mean knowledge gain of the respondents was 79% with respect to IPM practices on the castor and that contributes to the effectiveness of training through FFS. Similar results were reported by Rustam (2010).

Majority of the respondents (95.0%) were belonging to the 0-10 score category before imparting F'S training on castor IPM (Table 3). However, it was found at the post exposure training evaluation that, all the respondents fell under the score categories of 31-40. This distribution clearly indicates the extent of effectiveness of FFS on castor IPM practices imparted to respondents. There were no farmers under the 0-10 score category during first and second year after post exposure evaluation. During the first second and third years after post exposure evaluation, no or less portion of respondents were observed under 11-20 score categories. However, some considerable portions of the respondent were observed under 21-30 score categories during second year after post exposure evaluation and under 11-20 and 21-30 score categories during third years after post exposure evaluation. Only about two-third and half of the information could be remembered by the respondents after second and third years of training (Table 4), though about 90% of the information could be remembered after first years. This kind of distribution suggests that training programmes through FFS are to be imparted once after every two years to keep the respondents remembered and updated about IPM practices on the castor.

Conclusion: The FFS on IPM practices of castor seed production were very effective in imparting knowledge among tribal castor growers. Evaluation of knowledge retention of the framers toward IPM practices during the subsequent three years revealed that training programmes through FFS are to be imparted once after every two years to keep the respondents remembered and updated about IPM practices on the castor.

Table 2 Overall effectiveness of IPM training on knowledge gain (N=40)

Effectiveness parameters	In scores	In percentage
Mean pre exposure knowledge	7.7	21.0
Mean post exposure knowledge	36.7	100.0
Mean gained knowledge	29.0	79.0

Table 3 Distribution of respondents based on pre and post exposure scores

Score categories	Distribution of respondents (%)				
	Pre exposure	Post exposure	After post exposure		
			I year	*II year*	*III year*
0-10	95.0	0.0	0.0	0.0	5.0
11-20	5.0	0.0	5.0	12.5	47.5
21-30	0.0	0.0	17.5	42.5	32.5
31-40	0.0	100.0	77.5	45.0	15.0
Total	100.0	100.0	100.0	100.0	100.0

Table 4 Effectiveness of IPM training on knowledge retention over the years

Period	Mean knowledge score	% to the post-exposure score
Post-exposure	36.7	100.0
I year later	32.2	87.7
II years later	26.8	73.0
III years later	21.0	57.2

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Development of EST-SSR markers in castor (*Ricinus communis* L.)

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Abstract

Expressed sequence tag (EST) databases offer opportunity for the rapid development of simple sequence repeat (SSR) markers in crops. In the present study, sequence assembly and clustering of 57,895 castor ESTs resulted in the identification of 10,690 unigenes which clustered into 4501 contigs and 6459 singletons having 7429 SSRs. On an average, the unigenes contained 1SSR for every 1.23 Kb. The identified SSRs mostly consisted of *di-nucleotide (62.4%), and tri-nucleotide (33.5%) repeat motifs. AG/GA/CT/TC was the most common motif* (68.9%) among the di-nucleotides while AAG/AGA/GAA/CTT/TTC/TCT (25.9%) was the most common motif among the tri-nucleotides. A total of 611 primer pairs were designed for the class I EST-SSRs to convert them into PCR-based markers

Keywords: EST-SSR, castor, unigenes

Introduction

Molecular markers have proved to be a powerful tool in replacing bioassays and also in selecting the desired plants based on genotype rather than phenotype (which is influenced by environment and is also input as well as labour intensive) and thus reduce the cost of breeding varieties besides saving time. Among several DNA based markers, SSR markers, being co-dominant, PCR based and locus-specific, are more preferred. Development of SSR markers specific to castor is critical and should be a priority in the marker assisted breeding programmes of castor (Sujatha *et al.*, 2008). But, till date, only a very few SSR markers have been reported in castor (Allan *et al.*, 2008; Bajay *et al.*, 2009) since development of genomic SSRs is time-consuming and expensive process involving generation of genomic libraries and sequencing of large numbers of clones for finding the SSR containing DNA regions. The availability of castor EST sequences in the public domain provides an opportunity to develop EST-SSR markers in an easy and rapid manner, which could be deployed in castor improvement. It is interesting to note that EST-SSR markers developed from the related species rubber and cassava could be used in castor (Feng *et al.*, 2009 and Raji *et al.*, 2009). Till date, EST-SSR markers are not reported in castor. Therefore, the present study was carried out in order to identify SSRs and analyze their frequency and distribution in the ESTs of castor as well as to develop EST-SSR primers which could be used as potential markers for castor improvement.

Materials and methods

A total of 57,895 EST sequences (available during January 2009) of castor were downloaded from NCBI EST Database (http://www.ncbi.nlm.nih.gov/sites/entrez). In order to get non-redundant EST dataset for further SSR identification and primer designing, 57,895 ESTs were clustered and assembled through TGICL package (Pertea *et al.*, 2003) with the CAP3 (Huang and Madan 1999) default options. Based on regions of similarity, ESTs were merged into contigs. A total of 10,960 clusters consisting of 4501 contigs and 6459 singletons, putatively regarded as unigenes, were generated. SSRs were identified from these unigene sequences and primers were designed using the software SSR Locator (da Maia *et al.*, 2008). The criterion for the identification of SSRs was fixed in such a way that only those repeats wherein the motif was repeated ≥4 times were identified resulting in a minimum repeat length of 8 (in case of di-nucleotide repeats) to 24 (in case of hexa-nucleotide repeats) nucleotides. The SSRs were classified considering the complementarities of the repeat motifs according to the classification given by Jurka and Pethiyagoda (1995). The parameters used to design primers were: primer length of 18-24 bases, an optimal T_m of 58°C with a minimum and maximum of 54°C and 62°C, respectively, and a 40-60% GC content with a low chance of dimer or hair-loop formation. The range for PCR product length was set to be between 100 and 400 bp. SSRs were classified into perfect repeat (when one locus is present with adjacent loci at an up or downstream distance higher than 100 bp) and composite locus (when two or more adjacent repeat loci are at distances between 6 and 100 bp) (da Maia *et al.*, 2008).

Results and discussion

A set of 57,895 ESTs were subjected to redundancy analysis which clustered them into 10,690 unigenes that comprised of 6459 singletons and 4501 contigs. These 10,690 unigenes corresponding to 9125.5 Kb, were mined to search for SSRs, which resulted in identification of 7429 SSRs (Fig. 1; Table 1). The SSR frequency in this dataset was approximately 1 SSR for every 1.23 Kb of unigene sequences or 1 SSR in 1.48 unigenes on an average (Table 1). This frequency is higher than reports in several crops such as coffee (1/2.16), rubber (1/3.39 kb), cassava (1/7 kb), wheat (1/15.6 kb), barley (1/6.3 kb) and *Arabidopsis thaliana* (1/13.83 kb), tomato (1/11.1 kb), cotton (1/20.0 kb), soybean (1/7.4 kb) and poplar (1/14.0 kb), etc. These differences in different crops can be attributed to the different SSR search criteria, the size of the databases and the database mining tool(s) used and might not reflect the level of polymorphism of these SSRs in their respective species. It could also be due to the inherent higher levels of polymorphism shown by cross pollinated species compared to self

pollinated or clonally propagated crops. In general, when the minimum repeat length is 20 bp, microsatellites of various plant **species are present** in about 5% of ESTs.

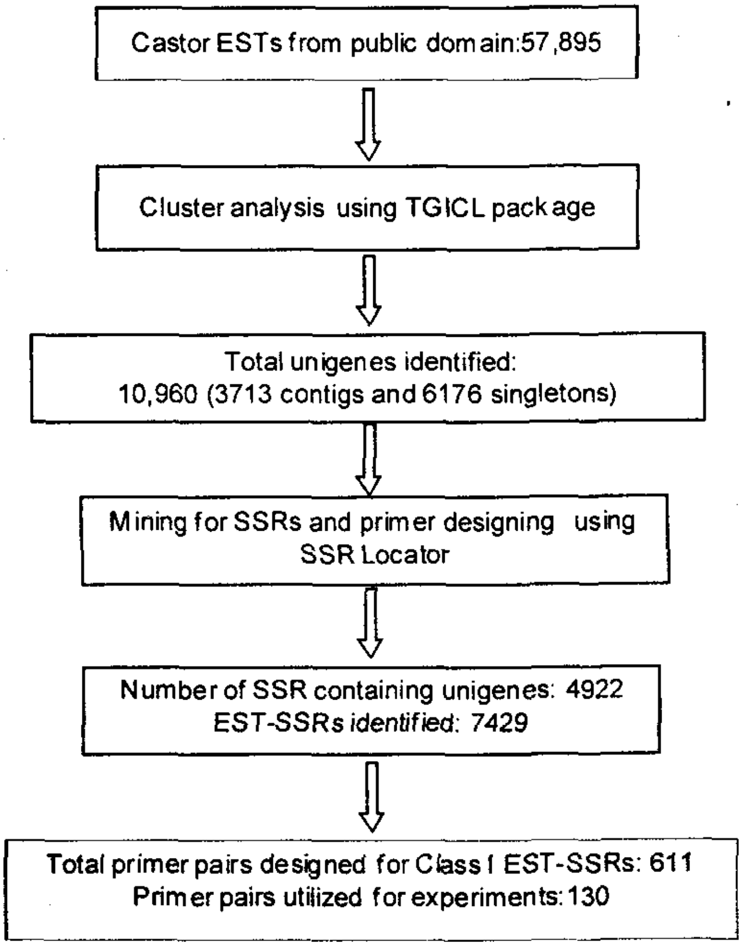

Fig. 1 Scheme for EST-SSR marker development in castor

Table 1 Details of the non-redundant EST-SSRs in castor

Total no. of sequences analyzed	No of unigenes	No. of SSRs identified	Frequency of SSR occurrence	No. of class I SSRs
57,895	10,960 (4501 contigs + 6459 singletons)	7429	1 SSR/1.23Kb	790

The identified SSRs occurred as composite loci (33.1%) and perfect repeats (66.9%). The majority (62.4%) of the unigene sequences had a single putative SSR while the remaining (37.6%) had 2-5 SSRs (Table 2). Considering the repeats in different reading frames or on complimentary strand, all the four classes that are possible for di-nucleotide, 10 for tri-nucleotide, and 33 for tetra-nucleotide repeats as reported by Jurka and Pethiyagoda (1995), have been included in the present study. It was observed that in castor, di-nucleotide motifs (62.4%) were most preponderant followed by tri-nucleotide motifs (33.5%) while in several other crops, tri-nucleotide motifs have been found to be more abundant. Abundance of di-nucleotide motifs has also been reported in peach, pumpkin, coffee, spruce, safflower, rubber and kiwi fruit. A lower frequency of other types of repeats i.e., 1.5% (tetra-), 0.7% (hexa-) and 0.2% (penta-) were detected (Fig. 2).

Table 2 Details of the Unigenes with 1 to 5 SSRs

No. of SSR motifs	No. of unigenes	No. of SSRs within composite loci	No. of SSRs as perfect repeats	Total No. of SSRs identified
SSR	3072 (62.4%)	-	3072	3072
SSRs	1432 (29.1%)	1598	1348	2946
SSRs	305 (6.2%)	513	414	927
SSRs	82 (1.7%)	221	108	329
SSRs	31 (0.6%)	130	25	155
Total	4922	2462	4967	7429

Among the di-nucleotide repeats, AG/GA/CT/TC motif was the most common (68.9%) (Fig. 3) and a similar result has been reported in several other plant species. Depending on the reading frame, a di-nucleotide motif can represent multiple codons and translate into different amino acids. For example, the GA/CT motif can represent GAG, AGA, UCU and CUC codons in a mRNA population and translate into the amino acids Arg, Glu, Ala and Leu, respectively. Ala and Leu are present in proteins at high frequencies of 8% and 10%, respectively. This could be one of the reasons why GA/CT motifs are abundant in EST collections. The CG/GC motif accounted for only 0.4% of the di-nucleotide repeats in this study and a similar least frequency of this motif has been observed in coffee, sugarcane and other monocots.

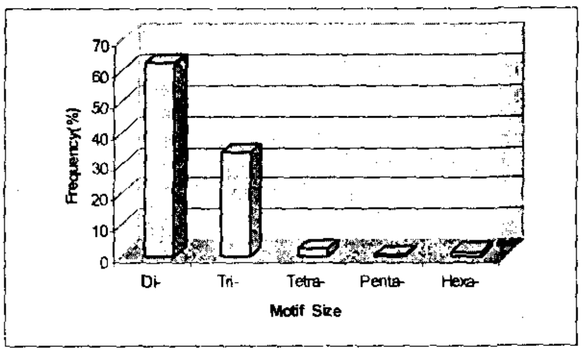

Fig. 2. Frequency of different types of repeats

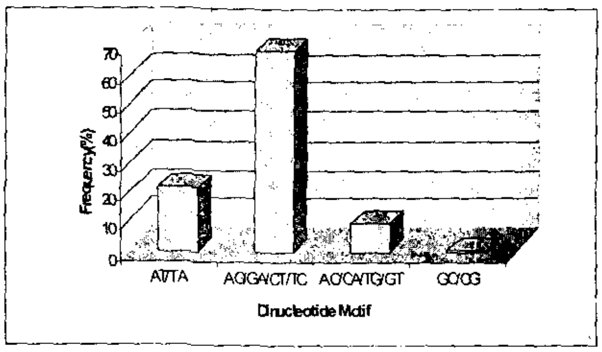

Fig. 2. Abundance of different motifs in dinucleotide repeats

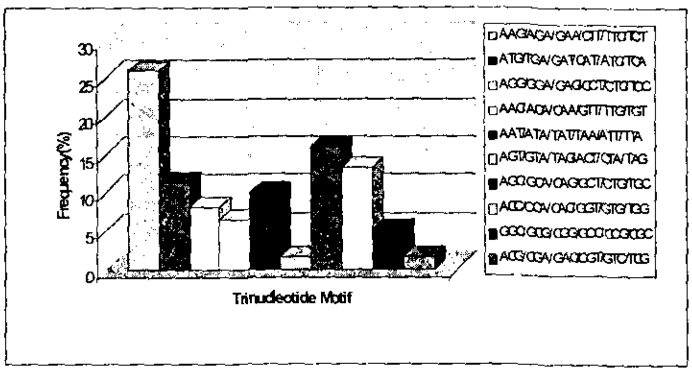

Fig. 4. Abudance of different motifs in trinucleotide repeats

Among the tri-nucleotide repeats, the motif AAG/AGA/GAA/CTT/TTC/TCT was predominant (25.9%) (Fig. 4), which was also the most abundant motif in majority of the dicotyledonous species including cotton, pine, soybean, *Arabidopsis*, safflower, rubber. On the contrary, the motif GGC/CGG was most abundant in monocotyledonous species such as barley, maize, sorghum and rice. However, comparison of the prevalence of a particular motif across crop species is difficult due to the differential criteria adopted by research groups for the identification of repeat motifs. It should be noted that, nucleotide composition might play an important role in the genesis of repeats, in the coding sequences, its effect on the structure and function of the encoded proteins would be a major selective force.

Interestingly, a comparison of the data obtained for castor in the present study with those of recent reports of EST-SSRs in rubber and cassava which also belong to Euphorbiaceae family, revealed that in all these, the di-nucleotide motifs are predominant followed by tri-nucleotide repeats. Also the AG/GA/CT/TC motif within di- repeats and the AAG class among the tri- repeats are most predominant in these crops too. However, the frequency of occurrence of SSRs in the EST sets varied among castor (1/1.23 kb), rubber (1/3.39 kb) and cassava (1/7 kb) (Feng *et al.*, 2009), (Raji *et al.*, 2009). This could be due to difference in the tools/criteria used in mining for SSRs

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Studies on insect-pests and their management in castor seed production

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Abstract

Studies were carried out on the dynamics of major insect pests and management strategies for the castor seed production programme at DOR, ICRISAT farm during 2008-09 and 2009-10. Castor semilooper, *Achaea janata* Linn during the early stage of the crop was effectively controlled by monocrotophos (0.05%) followed by quinolphos (0.05%) spray in addition to hand picking of grown up larvae were found to be effective, whereas later stages, larval parasitoid, *Microplitis maculipennis* Szepligate and insectivorous predatory birds kept the pest below economic threshold level (ETL). In the initial stage hand picking of egg masses and early stage gregarious larvae and spraying of four rounds of chlorpyriphos (0.05%) followed by acephate (0.075%) during vegetative and reproductive stages kept tobacco caterpillar, *Spodoptera litura* (Fabricius) population below ETL. Monocrotophos (0.05%) followed by acephate (0.075%) and endosulfan (0.05%) spray was effective for castor capsule borer, *Conogathus punctiferalis* (Guenee). Application of chlorpyriphos (0.05%) was found effective against the leaf *Liriomyza trifolii* (Burgess). Among different parents, DPC-9 and DCS-9 (Parents of DCH-177) the leaf miner infestation levels were higher (40-50%) compared to the parents of DCH-519 (M 574, DCS 98).

Keywords: *Castor, seed production, insect pests, management,*

Introduction

India is one of the major producers of castor (*Ricinus communis* L.) at the global level which dominates the international castor trade and earned foreign exchange to the tune of ₹2253 crores through export of castor oil and its derivatives during 2008-09. In India, maximum castor is produced in Gujarat followed by Rajasthan, Andhra Pradesh, Chhattisgarh, Karnataka, Orissa, Maharashtra, Haryana and Tamilnadu. In Andhra Pradesh castor is predominantly grown under rainfed agro-ecosystem of Ranga Reddy, Nalgonda and Mahaboobnagar districts. There are several production constraints like poor quality seeds of varieties and hybrids, low and erratic rainfall, shallow soils with poor fertility and low input use in castor in this region, which resulted in low productivity (DOR, 2010). In the castor ecosystem through 67 species of insects, five species of vertebrates and one mite species as herbivores, 48 species of natural enemies (seven parasitoids, 24 insect predators, nine spiders and eight predatory birds) and eight species of pollinators are associated (Basappa *et al.*,2009) but major insect pests like red hairy caterpillars (*Amsacta albistriga* Walker), castor semilooper (*Achaea janata* Linn), castor shoot and capsule borer, [*Conogathus punctiferalis* (Dichocrosis punctiferalis (Guenee)], tobacco caterpillar [*Spodoptera litura* (Fabricius)], leafhopper [*Empoasca flavescense* (Fabricius)] and hairy caterpillars [*Spilosoma obliqua* (Walker)], *Euproctis* spp and *Pericalia ricini* Fabricius) are of greater economic importance among major biological production constraints in this region. In recent years serpentine leaf miner, *Liriomyza trifolii* (Burgess) and thrips also cause damage to castor crop. Several natural enemies are found to exert greater biological resistance in the succession of insect pests of castor (Basappa, 2003). In recent years due to the severe incidence of major insect pests and diseases as well as lack of sufficient quantity of quality castor seed in this traditional castor growing area farmers, are switching over to other crops. To meet the national indents and satisfy the local requirements of seed demand, Directorate of Oilseeds Research (DOR) initiated certified quality seed production of its castor hybrids in its experimental farm at ICRISAT, Patancheru.

Materials and methods

The study was carried out during post-rainy/summer seasons of 2009-10 on Vertisols under irrigated conditions to examine the comparative insect pest dynamics and management of insects in hybrid seed production of two popular castor hybrids released by DOR, Hyderabad. Two hybrids *viz.*, DCH-177 (consisting of three rows of a female DPC-9 and one row of male DCS-9); DCH-519 (consisting of three rows of a female M-574 and one row of male DCS-78) was sown in blocks of 1 ha each. A spacing of 120 cm x 60 cm was followed on ridges and furrows. Male and female parents were sown simultaneously and the recommended agronomic practices for castor were followed. The foliar sprays of recommended pesticides were taken up through the tractor mounted ultra low volume sprayer. The characteristics of parents in relation to insect pest infestation are given in table 1.

Results and discussion

The data presented is based on the mean values of findings of 2008-09 and 2009-10. Major insect pests were above economic threshold level (ETL) (castor semilooper (4-5 larvae/plant), tobacco caterpillar (10-15% defoliation) and castor capsule borer (10% capsule damage) in both the years. Major insect pests recorded in castor seed production fields and insecticides sprayed along with yield obtained in both the years are presented in table 2.

Castor semilooper: During October up to 45 DAS semilopper infestation was seen on both parents of two hybrids alike and, which was easily controlled by resorting to hand picking. There was marked reduction in the castor semilooper population due to application of recommend insecticides *viz.*, monocrotophos (0.05%) followed by quinolphos (0.05%) during 2008-09 and 2009-10, respectively during the early stage. Later stages, larval parasitoid, *Microplitis maculipennis* Szepligate and insectivorous predatory birds like Indian mynah and black drongo kept the pest below ETL in both the years. Similar observations were made by Basappa (2009)

Tobacco caterpillar: The infestation of spodoptera was seen right from the initial stages and continued until maturity with typical symptoms of skeletenised leaves giving mesh like appearance by gregarious larvae. Initially, the pest was managed through hand picking of damaged leaves and collection of egg masses. However, the pest was not brought under control due to the outbreak which was observed in both the years which caused severe damage to foliage. Apart from defoliation, it also damaged tender castor capsules and spikes at reproductive stage of the crop. Whenever the crop was treated with insecticides the larvae exhibited avoidance behaviour by hiding in the cracks' crevices in the soil for 2-3 days after insecticide application. Due to nocturnal habit minimum population of tobacco caterpillar was observed on the plant during the daytime and damaged crop during night time. Tobacco caterpillar population was kept below ETL by repeated foliar sprays of recommended insecticides *viz.*, chlorpyriphos (0.05%) followed by application of acephate (0.075%) four rounds during vegetative and reproductive stages using a tractor mounted ultra low volume sprayer. Because of avoidance behaviour the activity of the pest was seen above ETL and hence in addition to chemical methods other mechanical methods like handpicking of egg masses and early stage larvae by walking in between two rows of castor regularly was resorted. The predation of grown up larvae by insectivorous predatory birds like house crow, common mynah and black drongo was observed in both the years. Similar observations were made earlier (Basappa, 2007).

Capsule borer: The incidence of capsule borer was above ETL (>10%) in both the years among all the parents of hybrids under study. The pest attacked the crop from flowering stage onwards until the capsule formation/maturity. Initially, it started its activity as a shoot borer and later damaged flowers and capsules. Since the larvae were concealed in the web material and inside the capsules the control was found difficult due to non-contact of the insecticide with the larvae. The pest was controlled by using monocrotophos (0.05%) followed by acephate (0.075%) and endosulfan 0.05%. Insectivorous predatory birds like common mynah and black drongo were found predating on capsule borer in both the years. Basappa (2006) made similar observations.

Leaf miner: The Serpentine leaf miner, *Liriomyza trifolii* (Burgess) is a polyphagous pest was first recorded in castor, a new host during rainy season 1991(Lakshminarayana *et al.*, 1992). During the present investigation, application of several rounds of insecticide spays for control of defoliators eliminated natural enemies of the serpentine leaf miners, *L. trifolii* which lead to the outbreak of the pest causing more than 50% damage to foliage through mines thus reducing the photosynthetic area. Among different parents, DPC-9 and DCS-9 (Parents of DCH-177) the leaf miner infestation levels were found to be higher (40-50%) compared to the parents of DCH-519 (M 574, DCS 98) (20-30%) due to differential bloom characteristics (Table 1). The outbreak of the leaf miners might be due to resistance development to commonly used insecticides. Similar observations were made by Parrella and Keil (1984) who found that *L. trifolii* to have a high potential for development of resistance to commonly used pesticides. The incidence was brought under control by removal of affected lower leaves and insecticidal spray with chlorpyriphos (0.05%). The leaf miner incidence was highest in castor cultivar DCS-9 (Jyothi) with 93.9 larval mines/leaf in bottom leaves and per cent leaf area infested was highest in the bottom leaves of DCH-32 with 55.7%. Among all the cultivars, PCH-1 was least affected in all the three types of leaves *viz.*, top, middle and bottom leaves followed by GCH-1 (Boreddy *et al.*, 2003).

Sucking pests: Apart from defoliators, sucking pests were noticed at the later stage of the crop. Among sucking pests, leaf hoppers were the most important pests raised during post-rainy and summer months. The bloom characteristics of different parents had significant bearing on the level of incidence of leaf hopper. The parents of DCH 177 (DPC 9 and DCS 9) were found to have higher damage levels with typical hopper burn symptoms might be due to zero and double bloom characters respectively (Basappa, 2003). The comparative infestation was low in parents of DCH 519 (M 574 and DCS 78) due to the presence of triple bloom characteristics. The incidence was brought under control by insecticidal spray with monocrotophos (0.05%).

Based on the yield data of hybrids, it was found that during post-rainy/summer season DCH-519 gave higher yields than DCH-177 due to better in-built insect resistance characters such as bloom presence, which requires further thorough investigations. Major insect pests occurring in castor seed production are poly phagous with high damage potential. Hence it needs multi-directional approach for their effective management in the castor seed production unlike commercial castor. The knowledge on damage potential of insect pests and their behaviour in the castor eco-system and their interaction with natural enemy complex is essential apart from effective cultural practices for profitable and economically viable castor seed production.

Table 1 Morphological characteristics of parents and hybrids in relation to pest infestation

Hybrid DCH 177			
Plant character	**DCH 177**	**DPC 9**	**DCS 9**
Hypocotyl anthocyanin colouration	Present	Present	Present
Stem colour	Red	Green	Red
Bloom	Single	Zero	Double
Anthocyanin pigmentation of young emerging leaves	Present	Present	Present
Hybrid DCH 519			
Plant character	**DCH 519**	**M 574**	**DCS 78**
Hypocotyl anthocyanin coloration	Absent	Medium	Medium
Stem colour	Green	Green	Green
Bloom	Triple	Triple	Double
Anthocyanin pigmentation of young emerging leaves	Absent	Absent	Absent

Table 2 Insect-pests and their management in castor seed production

Insect pest	Insecticide used	Yield (kg/ha) DCH-177 2008-09	2009-10	Mean	DCH-519 2008-09	2009-10	Mean
Castor semilooper	Monocrotophos (0.05%) followed by quinolphos (0.05%)	850	950	900	1100	1250	1175
Tobacco caterpillar	Chlorpyriphos (0.05%) followed by application of acephate (0.075%) four rounds						
Capsule borer	Monocrotophos (0.05%) followed by acephate (0.075%) and endosulfan 0.05%.						
Leafminer	Chlorpyriphos (0.05%).						
Leafhopper	Monocrotophos (0.05%).						

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Study on anatomical changes in castor roots caused by *Macrophomina phaseolina* (Tassi) Goid

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Abstract

Dry root rot caused by *Macrophomina phaseolina* (Tassi) Goid is one of the important diseases of castor. Histopathological examination of castor (cv. Aruna) roots after inoculation with *M. phaseolina* was carried out. Plants showing characteristic symptoms of dry root rot at 45 days after artificial inoculation of *M. phaseolina* were compared with untreated control. Gross anatomical changes in internal tissues were observed. Initially, infection was restricted to the root epidermal cells and later infection was also observed in cortical cells. Cell configuration, including organelles, became distorted. The *M. phaseolina* first infects xylem parenchyma and later xylem vessels in castor roots. Presence of mycelium of *M. phaseolina* in phloem, xylem vessels and vascular plugging were observed. Full growth and germination of sclerotia was observed only in meta xylem vessels. Disintegration of pith, inter and intra cellular penetration of mycelium in parenchyma was also observed. The externally visible symptoms of sudden wilting, straw colour discoloration with several black, erumpent minute pycnidia on stem are manifestation of pathogen infection.

Keywords: Castor, dry root rot, histopathology, *Macrophomina phaseolina*

Introduction

India is the largest producer of the castor (*Ricinus communis*) contributes to around 65% of the world's total production. The total area and production of castor in India are 6.25 lakh ha and 8 lakh t, respectively. Gujarat, Andhra Pradesh, Tamil Nadu and Maharashtra are major castor growing states in India. Castor crop suffer severe losses due to many diseases caused by fungi and bacteria. Root rot caused by *Macrophomina phaseolina* (Tassi) Goid was earlier considered as a disease of minor importance, but now it has become a devastating disease. The diagnostic features associated with root rot affected castor plants include turning of leaves to pale green colour accompanied with flaccidity and drooping. On stem, straw coloured discoloration with several black, erumpent minute pycnidia develop in concentric fashion giving a black appearance to these stem lesions. The infected roots turn to black and the blackened phloem of dead roots can easily be removed, leaving the central white stele (Kanakamahalakshmi *et al.*, 1999). The penetration and invasion of intra xylem vessels by *M .phaseolina* is seen in castor. It is envisaged that such knowledge would be of use to identify suitable chemicals for management of the disease.

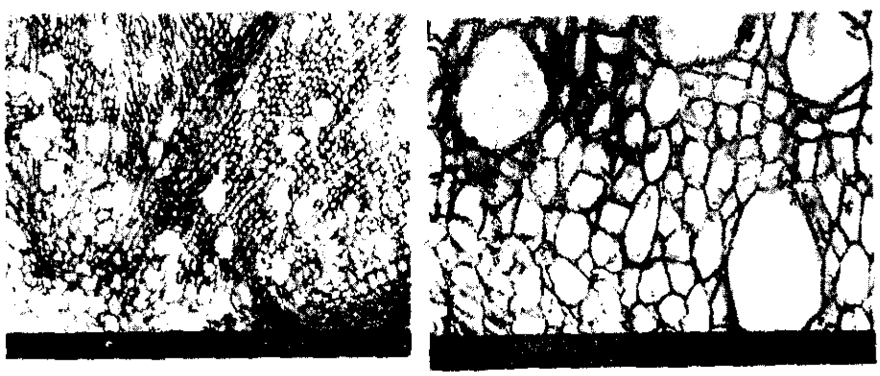
Materials and methods

The pots were filled with steam sterilized soil and were added with 2 week old culture of *M. phaseolina* grown on sorghum seed supplemented with glucose (2%). surface sterilized castor seeds (var. Aruna) were sown three days after inoculation and pots were irrigated. To study the histopathology of root rot of castor, 45 days old plants exhibiting typical symptoms of dry root rot disease were uprooted from the pots and washed with sterile water and used for detailed observations. Healthy un-inoculated roots from the plants of same age were used for comparison. About one cm blocks of root tissues from both *M. phaseolina* infected and healthy root samples were fixed in formalin acetic acid alcohol for 48 h, dehydrated in t-butyl alcohol and infiltrated with paraffin wax (58°-60°C). Paraffin embedded tissues were sectioned (12-14 μ thick), de-waxed with xylene, dehydrated through t-butyl alcohol series, stained with toulidine blue (0.2%) for 30 sec. Again dehydrated through ascending t-butyl alcohol series and brought to xylem. The sections were mounted in DPX mountant and examined under microscope.

Results and discussion

The anatomy of healthy root of castor consists of cork layer externally and the first phellogen originates in the cortex. A single endoderm layer was present. The pericycle consists of strong thick walled elements. The xylem is tetrarch and is visible even after considerable secondary thickening. The secondary xylem is characterized by the presence of large diameter vessels (Fig. 1).

M. phaseolina inoculated roots showed infection restricted to the root epidermal cells and cortical cells and disintegration of cortical tissues at later stages, where ever distinct brown lesions were formed externally. Observation of cell configuration including organelles was observed. Closer examination of affected vascular tissue revealed the disintegration of cell wall and middle lamella with emptying of cell contents. Mycelia were also seen in the disrupted cells. The cork layer disintegration was noticed at the site of infection (Fig. 3). In the vascular tissue, the fungus first infects xylem parenchyma followed by xylem vessels produce intra xylem mycelium and sclerotic bodies resulting into plugging of the xylem vessels. This is first report on presence of intra xylem mycelium and sclerotia in the *M. phaseolina* infected castor plant tissues. The pathogen produced intra xylem sclerotia both in protoxylem and metaxylem vessels. But the full growth and germination of sclerotia was observed only in metaxylem vessels. In protoxylem, the sclerotia were immature and abortive nature. Disintegration of pith region was also noticed. There was a total lack of cell coherence in parenchymatous cells of pith (Fig. 2). Histopathological studies revealed that the *M. phaseolina* is vascular in castor and causes sever damage to cells of cortex and parenchyma of pith. *M. phaseolina* form infection cushions and penetrates directly by means of infection pegs. Subsequently hyphae grow inter and intra cellular in the outer cortical tissues. The fungus primarily grows intercellular forming thick, short and dark coloured hyphae. The hyphae spread throughout the cortex, which result in disintegration of cortex and bark tissues. Similar observation in dry root rot of safflower crop has been reported by Kalpana Sastry and Pandey (1993). Singh (1990) also noticed disintegration of cortical tissues, plugging of xylem with mycelium and sclerotia in chickpea due to infection of *Rhizoctonia bataticola*. Disintegration of xylem parenchyma, phloem and cortical cells within three days of inoculation of roots of sorghum seedling with *M. phaseolina* was reported by Karunakar *et al.* (1992). The present findings were in agreement with the observations of the earlier researchers.



Xylem, phloem and pith tissues in healthy root of castor

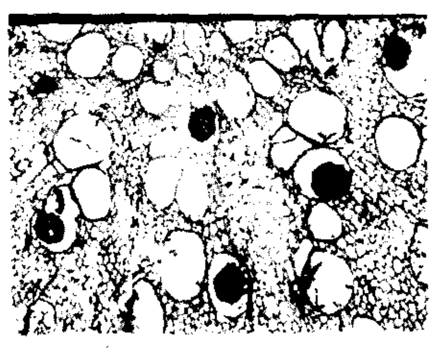


Fig. 2. Microtome section indicating presence of sclerotia in xylem vessels

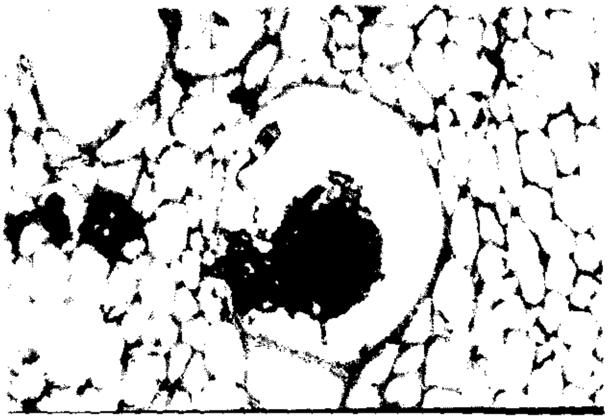


Fig. 3. Germination of sclerotia in meta xylem vessels and aborted sclerotia in xylem parenchyma

In the present investigation, histopathological studies indicated that the mechanical plugging of the xylem vessels by microsclerotia, toxin production, enzymatic action, and mechanical pressure during penetration lead to disease development. The cross section of the tissue revealed that sclerotial bodies were produced in the meta xylem and proto xylem cells. However, the sclerotial bodies formed in meta xylem are of normal size and germinated in spreading the infection. The sclerotia formed in the protoxylem and pith were of abortive in nature, which might be due to lack of space for their growth.

Formation of sclerotial bodies and production of mycelium in xylem vessels indicates that the fungus was both inter and intra cellular that plugs the xylem vessels and obstruct water movement in plants leading to externally visible symptoms of sudden wilting, black lesions near collar region and subsequent death of plants. In castor, the occurrence of sclerotial bodies of this nature in vascular elements and pith has not been reported earlier. The present study clearly explained the reason for dry root rot symptoms development which will be helpful in recommending suitable chemicals for control of dry root rot in castor.

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Characterising biotic stress in castor and other oilseed crops using multispectral radiometry

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Abstract

Present study demonstrated that by comparing the reflectance spectra generated using ground based multispectral radiometry, it is possible to distinguish not only healthy and pest/disease affected plants in oilseed crops but also the kind of pest/disease that induced the stress in those plant.

Keywords: Castor, biotic stress, multispectrum radiometry

Introduction

Pests and diseases cause serious economic losses in yield and quality of many oilseed crops. Detection and assessment of their damage symptoms is very crucial to initiate timely control interventions. Use of remote sensing techniques for detection of crop pests and diseases is based on the assumption that stresses induced by them interferes with photosynthesis and physical structure of the plant and affects the absorption of light energy and thus alter the reflectance spectrum of the plants (Riley 1989; Hatfield and Pinter, 1993). Hence by measuring the reflectance spectrum, the health status of a plant can be determined. Additionally remote sensing may provide a better means to objectively quantify disease stress than visual methods and it can be used to repeatedly collect sample measurements non-destructively and non-invasively. In this paper we report the changes in the reflectance spectra due to pest and disease incidence in two major oil seed crops *viz*., groundnut and castor.

Materials and methods

Canopy reflectance measurements were made with a hand-held multispectral radiometer (MSR 16-R, CropScan Inc., Rochester, MN, USA), which records incoming radiation and light reflectance with up-looking and down-looking sensors, respectively in 16 pass bands (460, 510, 560, 610, 660, 710, 760, 810, 870, 950, 1100, 1240, 1320, 1480, 1540 and 1650 nm). Each band has a half peak value of approximately 5 to 15 nm, depending on the specific pass band. The sensing method used is band-limited optical filters, which pass only wavelengths of irradiance in the pass-band range to the active surface of the detecting photodiode. Data on percent reflectance at each band were processed subsequently using the calibration and correlation constants through a mini computer connected to the sensor. The sensor head was mounted on an adjustable pole. The sensor receptor, facing the crop canopy was kept parallel to the ground surface, and the height of the sensor was maintained at 1.6 m above the crop canopy, which provided a view of 0.8 m diameter. A total of 10 samples were selected for each level of pest/disease. At each sampling, three measurements were recorded and the resulting data were averaged. The reflectance measurements were made near midday, within 2 hrs of solar noon.

Results and discussion

The reflectance spectra varied for different biotic stresses in the two crops. Higher reflectance in the NIR region between 760-1240 nm was observed for healthy plants compared to the affected plants in both the crops. The spectral signatures from severely defoliated (by semilooper) castor showed that the percent reflectance in the visible region between 560-710 nm was higher in the defoliated crop compared to healthy and reverse is true in the NIR region between 810-1100 nm. In case of groundnut, though the NIR region differentiated different levels of late leaf spot disease (Nutter, 1989), it was visible region where the termite infested plants showed maximum difference. Different spectral indices *viz*., SR (simple ratio), NDVI (normalized difference vegetation index), NPCI (normalized total pigment to chlorophyll index), DWSI (disease water stress index) and WI (water index) were compared to distinguish healthy and stressed plants. NDVI was found useful in distinguishing semilooper damaged (defoliated) castor crop from healthy castor. In case of groundnut, the differences in the spectral signatures between termite affected and healthy is more in visible region compared to NIR region and the spectral indices tested were found to differentiate the healthy and damaged plant. However, significant difference between three late leaf spot disease levels could not be observed. Efforts are under way to characterize spectral signatures using high resolution hyper-spectral radiometry, so that it would be possible to differentiate biotic and abiotic stresses and also to identify the narrow band hyper-spectral indices specific to the pest or disease.

Table 1 Changes in spectral indices due to pest and disease incidence in oilseed crops

Name of pest/disease	SR	NDVI	NPCI	DWSI	WI
Castor					
Semilooper-severely defoliated	1.9317	0.2753	0.4259	1.2561	1.1467
Healthy castor	1.8561	0.5377	0.4418	1.2679	1.1037
Groundnut					
Late leaf spot disease- low	1.7042	0.4316	0.3709	1.0602	1.1927
Late leaf spot disease- moderate	1.8135	0.5159	0.3384	1.1882	1.1977
Late leaf spot disease- severe	1.6803	0.4787	0.3564	1.1131	1.2512
Termites damaged	1.5244	0.3561	0.5111	0.9966	1.1213
Healthy groundnut	2.4479	0.6775	0.3656	1.6684	1.0761

SR: Simple Ratio; NDVI: Normalized Difference Vegetation Index; NPCI: Normalized Pigment to Chlorophyll Index; DWSI: Disease Water Stress Index; WI: Water band Index

Development of *Achaea janata* granulosis virus formulation for use as a viral biopesticide in the management of semilooper on castor

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Abstract

The Central Insecticide Board has given approvals for aqueous suspension formulations for Nuclear Polyhedrosis Viruses (NPVs) so far. Currently registered NPVs by CIB are Helicoverpa armigera and Spodoptera litura. Detailed

specifications have been developed for AjGV granulosis virus aqueous suspension 0.02% w/w (*Akaya-cide*) which will pave the way for its registration with the CIB under 9 (3b) provisions.

Keywords: *Achaea janata*, granulosis virus, biopesticide, castor

Introduction

Achaea janata (L.) (Lepidoptera: Noctuidae) is a serious pest of castor, *Ricinus communis* (L.). The pest completes several generations during the *kharif* season in castor growing tracts of Andhra Pradesh. The second and third generations of the pest on castor are economically important and cause serious defoliation if unchecked. Egg parasitoid, *Trichogramma* and larval parasitoid, *Microplitis maculipennis* (Szep) regulate the semilooper populations every year in nature (Prabhakar and Prasad, 2005). However, the action of these natural enemies is disrupted with insecticide use coinciding with their peak activity. *A granulosis* virus infecting semilooper (Prasad *et al.*, 2001) has been identified as a viral biopesticide with safety to the natural enemies (Prabhakar *et al.*, 2003). Development and testing of a formulation is essential to seek registration of the viral biopesticide with the Central Insecticide Board (CIB).

Materials and methods

An aqueous formulation of *Achaea janata* granulosis virus (AjGV) (AS 0.02% w/w) with anionic 0.5% sodium salt of Alkyl Aryl Sulfonate as surfactant and water as inert carrier was developed. Granulosis virus was extracted from homogenized diseased larvae and processed through differential centrifugation for developing the formulation. Suitable samples of Alkyl aryl sulfonate were obtained from the manufacturer for use in the formulations. Two other ingredients were tested for their suitability for incorporation in the formulation to increase the shelf life at ambient temperatures and test the efficacy for preventing build up of bacterial contaminants. Food grade chemicals of Potassium sorbate and Sorbic acid were tested at two concentrations. Virus samples of both primary culture and formulations (100 ml stocks with 5×10^{10} OBs m/l) were tested for bacterial contamination (all species) by determining the viable numbers according to the method of Miles and Misra (1938). Briefly, 10-fold serial dilutions of 0.1 ml stock were prepared and 20 µl was dropped from a height of 2.5 cm with a micropipette onto Luria or nutrient agar. At least 6 dilutions were plated in one Petri plate by marking equal segments underside the plate. Colonies were counted after overnight incubation at 35°C. The titre in colony-forming units (cfu) m/l of virus sample was computed from colony count (mean of six replicates) x 50 x Dilution factor. Similarly, titre of human pathogens was tested for Salmonella, Shigella on Hektoen enteric nutrient agar; Staphylococcus on Vogel-Johnson Agar Base, Lactose fermenting and Lactose non-fermenting enteric bacteria on McConkey Agar. One successful formulation was also submitted to an accredited independent certifying agency recognized by CIB for testing of active ingredient, contaminant profile and freedom from human pathogens. Also the formulations were evaluated against field population of semilooper on castor at 1×10^{13} capsules/ha and compared with neem seed kernel extract (NSKE 5%) and *Bacillus thuringiensis* (Bt) 0.15% sprays.

Table 1 Estimated bacterial contaminant load in granulosis virus primary culture and formulations

Granulosis virus culture	Mean Viable bacterial load (cfu m/l)
Primary culture	2×10^2
Formulations (Aqueous suspension)	
GV + 0.025% Potassium Sorbate	2.8×10^2
GV + 0.05% Potassium Sorbate	2.7×10^3
GV + 0.025% Sorbic acid	1.2×10^2
GV + 0.025% Sorbic acid	0.8×10^2
GV + 0.5% Alkyl Aryl Sulfonate Sodim salt	<10 colonies at all dilutions

* GV concentration in 100 ml of primary culture and formulations was 5 x 1010 Obs/ml

Table 2 Bioefficacy of AjGV formulations against castor semilooper under field conditions

Treatment*	Dosage (Spray fluid @ 500 litres/ha)	% Efficacy at 7 days after spray#
AjGV Formulation 1	1×10^{13} OBs/ha	70.0a
AjGV Formulation 2	1×10^{13} OBs/ha	40.0b
AjGV Formulation 3	1×10^{13} OBs/ha	36.7b
Neem seed kernel extract	5% spray	50.0b
Bt powder spray	0.15% spray	63.3a

* *Surfactant in formulation was Alkyl aryl sulfonate at 0.5% conc.; Potassium sorbate and Sorbic acid were used in formulations 2 and 3 respectively; No phytotoxicity symptoms were detected. Microplitis* incidence was similar in all the viral treatments and untreated control, indicating safety of the formulatons to natural enemies. #means followed by the same letter not significantly different (P=0.05%) as per DMRT.

The results indicate that all the formulations were within the permissible limits for contaminants prescribed by CIB i.e. 10^4 cfu/ml. Potassium sorbate and Sorbic acid formulations affected the physical stability of the virus (curdling of virus) over a period of time. Among the surfactants tested, the best formation both in terms of physical compatibility and stability with low levels of bacterial contaminants was with alkyl aryl sulfonate at 0.5% concentration (Table 1). All the formulations were free from human pathogens namely, Salmonella, Shigella and Vibrio which was confirmed by the independent testing agency. Among the formulations of AjGV tested, population reduction was 70% with the AjGV formulation containing 0.5% alkyl aryl sulfonate and was comparable to Bt but significantly superior to other formulations and NSKE spray (Table 2).

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Heterosis breeding in castor, *Ricinus communis* L.

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Abstract

The study of 50 crosses of castor derived from mating of 5 lines x 10 testers, suggested that considerable heterosis over the better parent was present for early flowering and fewer number of nodes upto main spike. It was in the desired direction and significant over the better parent in four crosses, each for capsules/main spike and seed yield/plant and in six crosses for oil content. For reduced plant height and increased length of main spike, significant heterosis over the better parent was absent. However, several crosses showing useful and/or significant superiority over the released hybrid ("GAUCH 1") could be noticed for these characters. The *sca* effects associated with these hybrids and significance of a line x tester interaction and predominance of *sca* variance for all the characters indicated dominance to over-dominance gene action responsible for observed heterosis.

Keywords: Heterosis, heterobeltiosis, castor

Introduction

The phenomenon of heterosis has prove to be the most important genetic tool in enhancing yields of self as well as cross pollinated crop plants. With the availability of pistillate lines in castor, exploitation of heterosis has become feasible and economical. The present day emphases is towards the development of high yielding hybrids of castor which can do better in a wide range of cropping system. The information on the extent of heterosis for yield and related characters as well as their underlying genetic basis generated through a line x tester study, is reported in this paper.

Materials and methods

Each of five female lines *viz.*, SKP 2, SKP 18, SKP 25, SKP 23 and VP 1 were crossed with ten male lines *viz.*, VI-9, 454, VH 52, SPS 43-3, SPS 35-9-B, SPS 35-50, HO, JM 4, SPS 49-4 and SH 5 using line x tester mating design. All the 50 hybrids and 15 parents were evaluated in randomized block design with three replications under the irrigated condition as Sardarkrushinagar. Each plot was comprised of single 6 m long row spaced 120 cm apart keeping 60 cm between two dibbles within a row. Recommended cultural practices were followed for growing the crop. The observations were recorded from five randomly selected plants in each plot for seven characters (Table 1). The data were subjected to analysis of variance as per standard statistical procedure. Heterosis was determined as the percentage increase in F_1 over the better parent and released hybrid GAUCH 1 (VP 1 x VI 9) used as a check. Combining ability analysis was done (Kempthorne, 1957).

Results and discussion

Existence of considerable heterosis was evident from the significant of parent hybrid interaction in the analysis of variance. The study of individual hybrid for various characters indicated that out of 50 hybrids, the heterosis was significant over respective better parents in the desired direction in 22 hybrids for days to flowering and 18 inbred for the number of nodes up to main spike. Similarly ,four hybrids depicted significant and useful heterosis for capsules/plant and seed yield/plant, whereas this was for six hybrids incase of oil content. Many hybrids showed shorter plant height and increased length of main spike over the better parent but this superiority was not significant. For each of the characters studied the useful hybrids were identified looking to their superiority over the better parent, released hybrid (GAUCH 1) and favorable sca effects. They are listed in table 1.

Three hybrids were significantly earlier in flowering than their better parents and GAUCH 1 with desirable heterosis as well as significantly negative *sca* effects. Though none of the crosses showed negative heterosis over the dwarf parent, five hybrids have significantly lesser plant height than GAUCH 1. All these hybrids were associated with significantly negative *sca* effects. The less number of nodes up to main spike, which results in earliness of hybrid, was found in four hybrids with significantly negative hybrid vigour over the better parent. Their superiority over GAUCH 1 was also negative so also the *sca* effects except for the hybrid of VP 1 x SPS 49-4 having the positive value of *sca* effect. For length of main spike and number of capsules/main spike, the promising hybrids were common.

All these hybrids had recorded highly significant superiority over GAUCH 1 though none of them were superior over the respective better parents. The highest increment over hybrid check was noted in VP 1 x JM 4 (87.0) for spike length and in SKP 25 x JM 4 (165.4) for capsule number. The *sca* effects on these hybrids were highly significant and positive indicating the role of non additive gene complexes in the expression of heterosis. Each of these hybrids had JM 4 as common male, and hence it could be a valuable genetic stock for increasing spike length and capsule number in castor crop. A marked degree of heterosis for spike length was also reported by Manivel *et al.* (2004) and for capsule numbers by Golakiya *et al.* (2004) and Patel (2004).

Table 1 Promising hybrids for various traits along with their *per se* performance, heterosis over better parent and GAUCH 1 and *sca* effects

Crosses			Mean value	(%) Heterosis over		*sca* effect
				better parent	GAUCH 1 (check)	
Days to flowering						
SKP 25	x	VI 9	37.3	-24.33**	-17.11**	-18.78**
SKP 18	x	VH 52	37.6	-20.98**	-16.40**	-16.91**
SKP 23	x	SH 5	40.0	-18.37**	-11.11	-14.11**
Plant height (cm)						
SKP 25	x	SH 5	27.3	-	-26.21**	-31.64**
SKP 18	x	SH 5	27.8	-4.82	-24.86**	-24.81**
SKP 23	x	SH 5	29.3	-	-20.81**	-28.37**
SKP 25	x	SPS 35-50	29.8	-	-19.46*	-23.13**
SKP 23	x	SPS 35-50	30.9	-	-16.49*	-21.53**
Number of nodes up to main spike						
SKP 8	x	SH 5	11.6	-10.29**	-04.92	-03.37**
VP 1	x	454	11.7	-17.39**	-04.10	-02.82**
SKP 25	x	SH 5	11.8	-02.24**	-03.28	-02.94**
VP 1	x	SPS 49-4	11.9	-15.99**	-02.46	01.89**
Length of main spike (cm)						
VP 1	x	JM 4	72.2	-	87.05**	53.93**
SKP 25	x	JM 4	64.2	-	66.32**	40.97**
SKP 2	x	JM 4	61.4	-	59.07**	40.17**
SKP 18	x	JM 4	56.6	-	46.11**	28.17**
SKP 23	x	JM 4	53.6	-	38.66**	27.07**
Number of capsules/main spike						
SKP 25	x	JM 4	133.0	-	165.47**	119.98**
SKP 18	x	JM 4	91.4	-	82.44**	62.96**
SKP 23	x	JM 4	88.0	-	75.65**	63.31**
VP 1	x	JM 4	83.6	-	66.67**	50.03**
SKP 2	x	JM 4	81.1	-	61.88**	51.52**
Oil content (%)						
SKP 23	x	SPS 49-4	50.8	20.88	12.64**	7.32**
SKP 25	x	SPS 49-4	48.9	1.79	8.43*	6.22**
SKP 18	x	JM 4	48.7	9.14*	7.98*	3.07**
SKP 25	x	SPS 43-3	48.5	1.06	7.54*	4.33**
VP 1	x	SPS 49-4	48.5	11.11**	7.54*	3.78**
Seed yield/plant (g)						
SKP 25	x	JM 4	502.3	-	24.64	132.37**
SKP 2	x	JM 4	484.3	-	20.17	251.03**
VP 1	x	HO	482.3	91.65	19.68	109.97**
SKP 23	x	454	479.6	57.79	19.01	71.31**
SKP 18	x	JM 4	435.3	-	8.03	76.03**

@ GAUCH 1 is a commercially grown hybrid of VP-1 x VI-9; *, ** P = 0.05 and 0.01 levels, respectively; (-) Desired heterosis was not observed

For oil content five hybrids were observed prosing with useful heterosis over the better parents, which was significant over the standard check. Similarly, of the five hybrids showing significantly more seed yield than GAUCH 1 and significantly positive *sca* effects, only two hybrids possessed heterosis over the better parents. The present results are in accordance with findings of Patel (2004), Golakiya *et al.* (2004) and Lavanya *et al.* (2006) who have reported considerable heterosis of seed yielding and capsules/main spike in castor.

The analysis of variance for combining ability (Table 2) suggested significance of additive and non additive gene action for all the characters except oil content. For oil content only non additive gene action was significant. However, the ratio of the variance due to specific combining ability to general combining ability for all the traits suggested importance of non additive gene action in the genetic control of these characters. Lavanya *et al.* (2006) reported similar results. This observation along with significant *sca* effects associated with various crosses suggested that the dominance to over dominance could be the genetic cause responsible for observed heterosis in the present study. The crosses like SKP 25 x JM 4 and SKP 2 x JM 4 needs favourable attention in their heterotic response for the seed yield, spike length and capsule number.

Table 2 ANOVA for line x tester mating design and ratio of variance components for different characters

Source	d.f.	Days to flowering	Plant height	Nodes up to main spike	Length of main spike	Capsules/main spike	Seed yield/plant	Oil content
Lines	4	34.35*	62.64**	0.93	160.30**	611.63**	3562.74*	6.31
Tester	9	85.92**	640.87**	6.97**	375.54**	890.02**	11576.65**	3.35
Line x Tester	36	12.83**	30.96**	0.48**	19.83**	85.20**	3723.96**	4.07**
$\sigma^2 sca/\sigma^2 gca$		1.30	5.33	23.33	5.10	5.76	18.24	-

*, ** P = 0.05 and 0.01 levels, respectively; (-) Ratio not worked out because of line and testers being non significant

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Stability analysis in castor (*Ricinus communis* L.) under rainfed condition in Chhattisgarh

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Abstract

Ten elite released varieties and hybrids of castor were evaluated for three years under rainfed conditions in Jagdalpur, Bastar region of Chattisgarh to identify stable, high yielding genotypes for the state. Castor genotype, GCH-5 was stable for seed yield while Kranthi, DCH-177 were stable for days to maturity and 100-seed weight.

Keywords: Stability analysis, Eberhert and Russell model.

Introduction

Castor, an important industrial, oilseed crop is grown in an area of 79,000 ha in Chattisgarh by tribal farmers for domestic purposes to a large extent. The productivity of local genotypes is low (304 kg/ha) while the average production is 24, 000 t (Damodaram and Hegde, 2008-09). The productivity of this crop can be increased by using high yielding, stable, disease and pest resistant hybrids. Several high yielding hybrids *viz.*, GCH-4, GCH-5, GCH-6, GCH-7, DCH-177, DCH-519 and varieties *viz.*, DCS-9, 48-1, Kranthi, Haritha, GC-2, etc., released either at the central or state level are available for commercial cultivation (AICRP on DOR, Castor, 2006). The present study is conducted to identify high yielding and stable castor hybrids and varieties suitable for Chattisgarh region.

Materials and methods

Ten elite release varieties/hybrids were evaluated at Shaheed Gundadhoor College of Agriculture and Research Station, Kumharawand, Jagdalpur, Bastar (Chhattisgarh) under All India Coordinated Research Project on castor during mid rainy season of 2004, 2005 and 2006 under rainfed conditions. The experiment materials were sown in a randomized complete block design with 3 replications. Each entry was sown in 5.4 m x 4.5 m plot, spaced 90 cm row to row and 45cm plant to plant. The recommended package of practice was followed to raise healthy crop. The observations were recorded on five randomly selected plants for plant height (cm) and effective branches/plant, days to 50% flowering, days to maturity, 100 seed weight (g) and seed yield (kg/ha.). For seed yield observation was recorded/plot basis and converted into kg/ha.

Results and discussion

Stability parameters along with plant performance of ten promising varieties/hybrids of castor were worked out for plant height (cm), effective branches/plant, days to 50% flowering, days to maturity, 100 seed weight (g) and seed yield (kg/ha.) under three different environmental conditions. Highly significant differences among genotypes were observed for all the characters. The significant genotype x environment interaction was recorded for plant height (cm) and days to maturity. Environment (linear) interaction component was significant for all the traits except effective primary branches/plant, while the linear component of environment interaction was significant for plant height and days to maturity. The variance due to pooled deviation (non linear) was highly significant for all the characters studied which reflect considerable genetic diversity in seed yield. Hybrids *viz.*, DCH-32, DCH-177, GCH-5, RHC-1and varieties *viz.*, 48-1 and JCR-5(local check) were stable for plant height. Variety DCS-9, 48-1 and hybrid GCH-5 were stable for effective branches/plant. None of the varieties/hybrids were stable for days to 50% flowering. Variety Kranthi and hybrid DCH-177 were stable for days to maturity and 100 seed weight (g). Only hybrid GCH-5 was stable for seed yield (Table 1 and 2).

Table 1 Estimates of different stability parameters for plant height, effective branches/plant, days to 50% flowering in castor

Genotype	Plant height (cm)			Branches/plant			Days to 50%flowering		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
DCS-9	48. 30	5.68	-4.99	3.60	-1.38	-0.02	64.66	0.74	7.56 **
48-1	53.94	6.83	6.27	3.16	9.92	0.02	69.66	-0.05	10.43 **
Kranthi	49.59	-0.24	-5.86	3.43	15.00	0.14 *	68.44	1.09	0.11
DCH-32	56.30	0.14	-3.82	2.64	6.15	0.06	66.77	1.02	3.05 **
DCH-177	55.41	-2.62	-5.98	3.63	-11.30	0.47 **	69.00	-0.19 *	-0.21
GCH-4	47.27	2.00	-6.20	2.96	0.23	0.36**	64.55	2.38	-0.11
GCH-5	61.84	-2.80	-5.90	4.23	-6.46	0.03	75.33	0.76	2.69 **
GCH-6	50.15	-0.38	-5.21	2.63	1.15	0.04	69.22	-0.28	0.74 *
RHC-1	53.81	-1.23	-6.08	2.93	7.38	0.87 **	63.77	2.57 *	-0.21
Local	53.13	2.61	-6.19	1.51	-10.69	-0.03	88.11	1.95	2.18 **
Mean	52.97	1.0		3.07	1.0		69.95	1.0	
SEm±		0.85			9.84			0.70	

*, ** = Significant at 5% and 1% levels, respectively

Table 2 Estimates of different stability parameters for days to maturity, 100 seed weight (g), seed yield (kg/ha) in castor

Genotype	Days to maturity			100 seed weight (g.)			Seed yield (kg/ha.)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
DCS-9	128.9	10.91 *	4.4*	26.40	4.88	1.38**	1298.6	-0.82	37236.6***
48-1	123.6	-1.57	0.1	24.66	1.07	1.91 **	937.9	1.31	327.3
Kranthi	109.9	-0.51	-0.4-	24.91	-2.41	-0.05	1243.6	-0.24	75728.9***
DCH-32	105.2	0.18*	0.8	21.53	2.22*	-0.13	1196.9	0.90	18188.6***
DCH-177	108.9	-0.11	1.2	26.40	1.31	0.16	1314.6	2.20	46101.4***
GCH-4	107.2	0.18*	-0.8	22.65	0.53	1.77 **	1332.7	2.57	95114.4***
GCH-5	115.9	-1.28	4.5*	24.64	0.52	1.64 **	1196.8	1.49	693.6
GCH-6	119.2	-1.07	3.1*	22.54	-0.38	-0.11	1084.8	1.44	-294.4
RHC-1	112.9	2.42	14.5***	23.50	1.55	2.89 **	1104.9	-0.56 *	-1002
Local	136.6	0.85	-01	23.56	0.69	0.54 *	615.1	1.71	6472.2***
Mean	116.8	1.0		24.08	1.0		1132.6	1.0	
SEm ±		0.6			1.28			1.2	

*, ** = Significant at 5% and 1% levels, respectively

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Estimation of stability parameters for yield and its various traits in castor, *Ricinus communis* L.

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Abstract

Fourteen genotypes of castor were evaluated for stability of grain yield and nine yield contributing characters over three years. Genotypes x environment interaction was found significant for days to 50% flowering, plant height (cm) up to primary raceme, effective primary spike length(cm), no. of capsules/primary spike, no. of effective spikes/ plant, 100 seed weight (g), oil content (%), seed yield (kg/ha). On partitioning it in to linear and non-linear components, both were responsible for expression of the traits. However, the linear component was found larger in magnitude than the non-linear component for character plant height (cm) up to primary raceme, effective primary spike length(cm), no. of capsules/primary spike, no. of effective spikes/plant, 100 seed weight (g) and oil content (%) suggesting that the variation in the performance of different cultivars could be predicted. None of the genotypes were found to be stable for seed yield. Genotypes JC-12 and 48-1 were found to be stable for days to 50% flowering. Genotypes JC-3 and JC-4 were found stable for number of nodes to primary raceme JC-12 and JC-18 had stability for effective primary spike length whereas JC-6 showed stability for number of branches/plant over different years. Thus these genotypes could be included in the hybridization programme to converge the stability characteristics of genotypes for development of a stable variety adapted for commercial cultivation.

Keywords: Castor G x E interactions, stability, regression coefficients

Introduction

Castor occupies an important place in the country. In India crop is grown in an area of 6.3 lakh ha, with a production of 7.6 lakh t and productivity of 1213 kg/ha (2006-07). During recent years, castor has emerged as a potential commercial crop by exporting oil and seeds and earning valuable foreign exchange. India accounts for 54% of global castor area and 51% of the world castor production and ranks first in the area and production in the world. It ideally suits for dryland farming in the rainy season and with limited irrigation in post monsoon both in traditional and non traditional areas. Castor is considered to be a good contingent crop in case of monsoon aberration providing a cushion to resource poor farmers of rainfed areas. Information about phenotypic stability is useful for the selection of crop varieties as well as for breeding programmes. An understanding of environmental and genotypic causes leading to genotype x environmental interactions are important at all stages of plant breeding including parental selection, traits and selection based on yield. This understanding can be used to establish breeding objectives and formulate recommendations for areas of optimal cultivar adaptation. Thus, this study was undertaken to evaluate castor genotype for their yield stability.

Materials and methods

Field experiments were conducted consisting of 14 genotypes of castor at Agricultural land of JNKVV, Zonal Agricultural Research Station, Chandangaon, Chhindwara (M.P.) in a randomized block design with two replications, with a spacing of 90 cm x 60 cm, in three successive years *viz.*, 2007-08, 2008-09 and 2009-10. The sowing was done by dibbling methods in the month of June each year. The rains received during these years in cropping period were 820mm, 767 and 917mm with 51, 48 and 61 number of rainy days respectively. The data were recorded on five randomly selected competitive plants in each replications and years for each genotypes on seed yield and different yield attributing traits *viz.* days to 50% flowering, number of nodes to primary raceme, number of branches/plant, plant height (cm) up to primary raceme, effective primary spike length (cm), number of capsules/primary spike, number of effective spikes/plant and 100 seed weight (g). The oil percentage was estimated separately. Considering each year as a separate environment, the mean values were subjected to stability analysis (Eberhart and Russell, 1966).

Results and discussion

Analysis of variance (Table 1) revealed significant differences among genotypes for all traits studied and environments except number of branches/plant, number of capsules/ primary spike and oil content suggesting the presence of variability among genotypes and environments. Significant mean squares for genotypes x environments interactions were observed for all traits except number of nodes to primary raceme and number of branches/plant indicating differential response of genotypes to different environments. Significant mean squares due to environment (linear) except number of branches/plant and number of capsules/primary spike indicated considerable differences among environments and their predominant effects on these traits. Genotypes x environment (linear) interaction was significant for character for plant height up to primary raceme, effective primary spike length, number of capsules/ primary spike, number of effective spikes/plant and 100 seed weight emphasizing the importance of liner regression in the predication of these significant traits with some. reliance under different environments. Significant pooled deviations indicate predominance of non-liner component in the manifestation of genotypes x environments interaction for significant traits. The present findings are in conformity with the findings of Henary and Dauley (1985), Laureti (1995) and Patel and Pathak (2006). However, for the unpredictable traits, prediction can be made considering the stability parameters of individual genotypes. According to Eberhart and Russell (1966) model a variety is considered to be stable if it shows high mean performance with unit regression coefficient (bi=1) and minimum deviation (non significant) from the regression ($S^2di=0$) (Table 1). Based on the mean performance, regression coefficient and deviation from regression values, stable genotypes have been identified (Table 2) for favourable and unfavorable environments in yield and its components and related traits. Stable genotypes identified in the study can be used to either directly for commercial cultivation or development of stable hybrids and breeding material.

Table 1 Stability parameters of 14 castor genotypes for seed yield and yield contributing traits

Genotypes	Sta. para meters	50% flowering	Raceme/ plant	Branches/ plant	Plant height (cm)	Spike length	Capsules/ spike	Spikes/ plant	Seed weight (g)	Oil (%)	Seed yield (kg/ha)
JC-1	x	54.83	14.00	5.33	96.00	63.33	67.50	17.50	42.17	52.12	3781.00
	bi	1.20	1.61	2.50	1.80	2.70	8.21	-0.73	-0.36	-4.12	0.39
	S^2di	0.94	0.67	0.72	51.72	8.43	0.94	9.22	1.46	0.23	124085.94
JC-2	x	50.17	11.17	4.83	65.67	58.17	58.33	16.33	33.22	48.84	3442.33
	bi	2.73	1.37	3.00	1.74	2.48	7.86	1.10	0.21	5.87	0.30
	S^2di	2.75	0.67	0.02	107.30	2.66	0.56	0.81	0.57	0.44	2783.84
JC-3	x	53.67	13.67	5.50	89.50	61.33	68.67	18.67	37.45	50.53	3723.67
	bi	1.16	0.98	0.00	1.77	2.29	5.03	-1.73	1.65	5.58	0.59
	S^2di	1.88	0.86	0.00	0.21	10.90	0.03	0.80	0.43	0.67	22730.66
JC-4	x	59.17	15.83	4.67	107.33	77.83	82.00	12.50	44.36	48.99	3195.00
	bi	1.27	1.07	1.50	1.27	0.59	-1.43	0.26	0.58	1.29	0.55
	S^2di	0.03	0.30	0.01	41.46	21.32	0.00	0.40	0.41	0.24	899.66
JC-5	x	50.33	11.50	7.17	48.67	46.50	48.83	23.50	33.32	50.68	3657.83
	bi	0.90	0.00	-3.00	-0.18	0.15	-3.10	2.02	-1.12	-0.53	1.47
	S^2di	1.09	0.00	0.02	116.71	0.24	7.80	0.22	0.74	0.05	7517.85
JC-6	x	54.33	14.50	4.33	78.00	70.17	73.67	16.00	41.60	49.01	3903.67
	bi	-0.03	1.66	1.00	0.40	2.47	-1.58	0.63	-1.14	1.61	1.22
	S^2di	2.16	1.11	0.10	5.83	12.02	10.24	1.39	0.71	0.01	91426.98
JC-8	x	55.33	14.67	5.50	88.00	69.33	72.33	17.67	33.72	51.15	3983.83
	bi	0.67	0.54	0.00	0.89	0.14	-2.50	0.55	1.12	5.09	1.14
	S^2di	10.41	0.07	0.00	24.77	2.46	68.60	0.20	0.35	1.16	138256.31
JC-10	x	53.00	12.50	5.67	61.00	54.67	57.83	18.67	35.72	49.98	3473.50
	bi	0.62	0.00	0.00	0.25	0.79	7.26	3.65	0.38	2.12	2.57
	S^2di	0.08	0.00	1.17	13.66	1.85	2.97	1.66	0.03	0.00	7237.86
48-1	x	58.17	15.00	5.17	92.33	54.00	49.17	21.33	38.70	52.01	2660.00
	bi	1.06	1.22	2.00	1.75	0.51	-7.81	-2.94	40.6	-1.12	0.84
	S^2di	0.49	0.02	0.38	156.32	3.14	35.91	3.35	1.56	0.04	3443.10
JC-12	x	58.83	14.67	6.33	79.67	74.00	83.00	14.17	43.39	49.86	3930.33
	bi	1.01	2.20	2.50	-0.14	1.02	-8.71	2.37	0.64	0.96	2.70
	S^2di	5.03	0.61	0.72	140.47	12.56	4.29	3.50	0.10	0.02	26788.52
JC-14	x	55.50	14.50	5.50	81.67	65.00	72.33	16.50	38.76	51.63	4018.00
	bi	1.33	0.83	-1.00	0.85	0.82	6.43	2.91	4.00	0.93	-0.16
	S^2di	1.54	0.28	1.93	19.51	0.98	0.47	1.03	2.71	0.54	29603.89
JC-16	x	61.17	16.50	7.17	10.3.83	63.33	80.33	13.50	37.40	50.86	3421.00
	bi	0.24	2.05	-1.00	1.17	0.96	3.01	1.82	2.80	-0.83	0.06
	S^2di	0.89	0.15	0.10	21.09	0.59	9.84	5.38	0.15	0.13	43844.29
JC-18	x	58.33	14.50	5.50	97.83	71.33	80.67	16.00	37.36	50.50	3860.50
	bi	1.72	-0.06	5.00	2.36	0.96	1.95	1.77	0.36	-1.45	0.77
	S^2di	0.34	3.50	0.21	104.32	0.59	20.98	1.21	0.55	0.31	877.67
DCS-9	x	48.50	11.17	6.33	50.50	51.67	54.33	19.50	31.42	48.82	2713.33
	bi	0.12	0.54	1.50	0.08	-0.34	-0.62	2.02	0.83	-1.23	1.56
	S^2di	9.43	0.07	1.01	9.33	1.40	4.29	0.22	0.14	1.43	36506.86
P.mean		55.09	13.87	5.64	81.43	62.91	67.79	17.27	37.76	50.36	3554.57
SEbi±		0.76	1.31	2.53	0.51	0.72	3.50	1.15	0.78	2.10	1.12
SEm±		1.15	0.52	0.48	5.39	1.68	2.44	1.01	0.59	0.43	138.36

Table 2 Stable castor genotypes over different years

Characters	Genotypes identified for		
	All environments	Less favourable environment	Favourable environment
Days to 50% flowering	JC-12 , 48-1	JC-5	JC-1
No. of nodes to primary raceme	JC-4, JC-3	-	JC-4 , 48-1
No. of branches/plant	JC-6	-	JC-4 , DCS-9
Plant height (cm) up to primary raceme	-	JC-8 , JC-14	JC-1 , JC-3
Effective primary spike length (cm)	JC-12, JC-18	JC-10 , JC-14	-
No. of capsules/primary spike	-	-	JC-18
No. of effective spikes/plant	-	JC-6 ,	JC-2 , JC-18
100 seed weight (g)	-	JC-12 , DCS-9	JC-3 , JC-8
Oil content (%)	-	JC-14 , JC-12	JC-4 , JC-6
Seed yield (kg/ha)	-	JC-4 , 48-1, JC-18	JC-6 , JC-8

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Development of precision ridger planter for castor crop for *in situ* water conservation

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Abstract

Castor crop is grown under rainfed conditions in which the productivity is very low because of adverse whether conditions in addition to limited resources with poor soils. Hence the resource management and timeliness of operations play a key role to increase the productivity under dryland conditions. Sowing is considered as most critical operation as many of the soils lack the good fertility status. Though the castor was grown with many of the commercial seed drills successfully, still there was need to develop a new planter which has to give good germination percentage in the climate change scenario. A precision ridger planter was developed at Central Research Institute for Dryland Agriculture. It is observed that the furrows formed by the planter were more precise and consolidated and facility to conserve the water during low and moderate rains and acted as drainage channels for excess rains because of which the crop was saved. The present study focuses the development and performance evaluation of ridger planter for castor crop.

Keywords: Precision ridger planter, conservation furrows, moisture conservation, plant population

Introduction

Castor is one of the important oilseed crop having high plasticity suiting to wide range of soil environments and capacity to adjust its growth according to moisture availability conditions of the soil. Once, the soil moisture increase after prolonged ought, castor rejuvenates quickly and puts up its growth at faster rate as compared to other oilseed crops. The chances of multiple harvests of beans is more and it may bring assured income to the farmers even under low moisture conditions. Castor is one of the major oil seed crop grown mostly under rainfed conditions in Andhra Pradesh, Maharashtra, Gujarat, Karnataka and Tamilnadu occupying 10.77 lakh ha area with annual production of 8.67 lakh t. Productivity of castor seed ranges from 3-8 q/ha which is very low (Damodaram and Hegde, 2007). It fetches good remunerative price and provides assured income to the farmers. As the dryland agriculture is a gamble with monsoon, moisture availability period is critical for germination of seed. In most cases, sowing is limited to 2-5 days (Mayande et al., 2002). Success of dryland farming depends on completion of all operations within limited time period. However, in many cases all the field operations are done by manual labour with bullock drawn implements. Because of all these reasons cultivation cost of castor is increasing gradually in all regions and labour shortage is being acute.

In conventional practice, sowing is done with the country plow, which become cumbersome. Besides time consuming, the manual dropping of seeds does not ensure proper plant stand leading to poor yields (Suryavanshi, et al., 1993). Since many of the soils in castor growing area are degraded. The depth of the seed placement varies as per the soil resistance. In most of the cases, fertilizer falls away from the seed when applied manually. All these factors effect the crop germination and plant growth. Mechanization of sowing operation by using the CRIDA planter increased the yields alone by 15% (Srinivas et al., 2009). This could be due to the placement of seed and fertilizer at proper depth and spacing in the moisture zone which is very critical as far as the drylands are concerned. However, it is observed that the dryland soils are more prone for erosion even with small amount of rainfall. It is frequently observed that the arid and semi arid zones receives good rainfall during the first part of rainy season followed by dry spells in consecutive fortnights. Hence, the in situ water has to be tapped to remove the moisture stress from the root zone. Dryland farming system should deal with seed, soil, watersheds, use of weather forecast, various measures to save the crop under aboitic stresses like drought and flooding, reclamation of degraded land through organic recycling, etc. Efforts were made at Haryana Agricultural University, Hisar, India to develop a seed drill for sowing crops on ridges where furrows, created on both sides of the ridge, help irrigation water to flow. The sowing of wheat crop using this method resulted in a saving in irrigation water upto 40-50 % and a 10% increase in grain yield (Kushwaha, 2001). The concept of sowing of crops on the slant surfaces of a specifically created furrow was devised by Central Arid Zone Research Institute, Jodhpur, India in which furrow facilitated the collection of runoff water to create and maintain a high moisture concentration in the plant root zone, resulting 26% increases in plant height and 30-70% increase in grain yield compared to the conventional method. The same method was tried at CRIDA, Hyderabad, India. But the planting on slanted edges resulted in poor germination because of sunken seed effect and also due to the nature of soil in the semi arid zone where alfisols with crust formation. In addition to, it is also felt that there is need develop a ridger planter with more precision to suit to the needs of all the soils and wide spaced crops which are common in this region.

Materials and methods

The earlier models of ridger seeders developed by the other institutes were evaluated at the field level during 2007, 2008 rainy seasons and found that they are unable to meet the required germination efficiency for castor crop. Hence, a 3-row ridger seeder was designed and developed at CRIDA workshop. The main experimental place for conducting the trail was near to the Hyderabad district which consists of light loamy and sand loamy soils with less organic matter. Hence, it is decided to make broader furrows for more water conservation to increase the in situ moisture holding capacity.

A tractor drawn ridger planter (Fig.1) which consisted a rigid frame with 2500 mm length, 750mm width and 600 mm height on which a seed cum fertilizer box was placed which has dimensions of 1800 mm length, 420 mm height and 300 mm width. Four symmetrical ridgers of 310 mm height and 270mm length with 450-700mm adjustable width were fitted on the frame. A flattening roller was fixed on each ridger wing to flatten the soil raised by the ridger as shown in fig.2. Specially designed inclined metering mechanism was used to drop the castor seeds in at 60 cm distance. Separate ground wheel drive mechanisms for seed and fertilizer dropping were used for more precision. Three tynes were bolted on the frame for opening the soil on the ridges formed by the ridgers. Seed and fertilizers were dropped behind the soil openers as shown in fig.1. Width of the furrow was maintained around 60 cm with 20 cm depth.

A spring auger mechanism which is first of its kind to meter the fertilizer was used in the fertilizer box which was dropped through the tubes. The equipment was calibrated to pickup one seed at a time by adjusting the angle of the seed and fertilizer box. The fertilizer dose was adjusted for 100kg DAP/ ha as per the recommendation. Tests were conducted at the institute farm and farmers fields simultaneously. Seed to seed distance, depth of seed placement were taken to find out the placement accuracy and efficiency of the machine. Germination percentage and yields were also recorded for two kharif seasons. Similar trials were conducted with farm's practice and conventional seed drill to compare the results.

Results and discussion

It is observed from the table 1, that the seed to seed distance with precision ridger seeder is found to around 580 mm which is very close to the targeted distance of 600 mm. In farmer's method, the female labour tried to drop the seed within the recommended spacing. However, the human efficiency could not meet the standard plant to plant and depth of seed placement. The same was observed with the conventional seed drill.

The resulted yield from the precision ridger planter showed an increase in yield by 34 % when compared to the farmer's method and 22 % over conventional seed drill. This might be due to the availability of more moisture in the root zone of the castor with ridge and furrow system. It is also observed in the season that the furrows helped to conserve the water during low to medium rainfall situations and also helped in draining the excess water during excess rains. This technology can be recommended to all types of soils as there is no crust formation was observed with the seed placement mechanism.

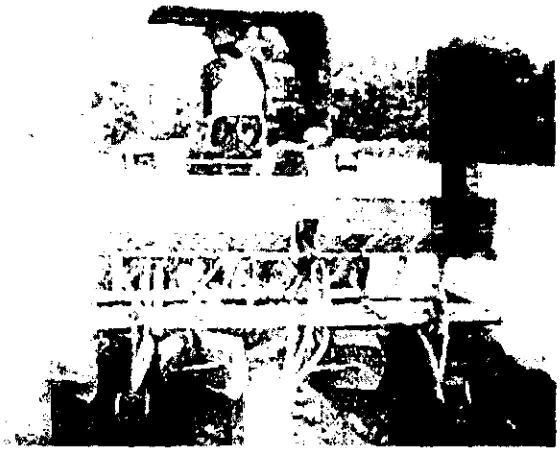

Fig. 1. Three row precision ridger planter

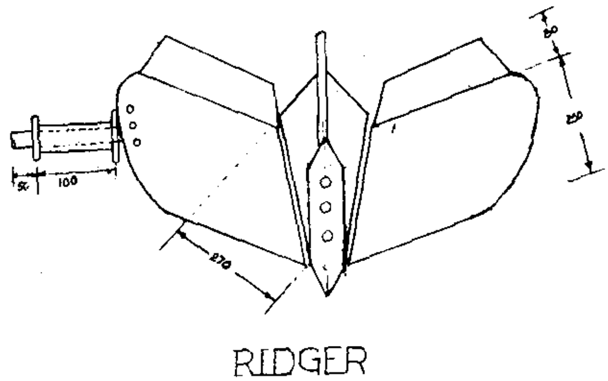

Fig. 2. Ridger with flattening roller

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Optimization of fertilizer requirement for castor (*Ricinus communis* L.) under rainfed conditions of Chhattisgarh

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Abstract

A field experiment was conducted during 2006-07 on a sandy loam soil, to find out the optimum dose of fertilizer for castor under rainfed situation of Chhattisgarh. The treatments consisted combinations of 4 levels of nitrogen (0, 40, 80 and 120 kg/ha), 3 levels of phosphorus (0, 30 and 60 kg/ha) and 2 levels of potassium (0 and 30 kg/ha). Nitrogen fertilization up to 80 kg/ha significantly increased seed yield of castor. Application of 30 kg/ha phosphorus was found superior to the control but it was statistically at par with 60 kg/ha in increasing seed yield. Significant variation on yield was observed due to potassium application of 30 kg/ha than that of the control. The quadratic response function study revealed that application of N and P2O5 at 56.8 and 36.0 kg/ha were optimum for achieving the seed yield of 692.2 and 685.4 kg/ha, respectively.

Keywords : Castor, nitrogen, phosphorus, potassium

Introduction

Castor is an ancient crop usually grown in marginal, sub-marginal and neglected lands with poor management under rainfed conditions. This oilseed crop has tremendous scope of extensive cultivation in Chhattisgarh especially in Bastar plateau region and it may uplift the poor economic condition of the farmers. Nutrients play vital role to harness the potential yield of any crop. Balance application of fertilizer improves vegetative growth, increases spike length results in more effective spike/plant. Newly developed genotypes of castor are different from the traditional ones in terms of morphology, duration, growth response and productivity (Raghavaiah *et al.*, 2003). Fertilizer requirement of castor hybrid vary substantially with agro-climatic conditions. Since information pertaining to above aspects is meagre, the present investigation was carried out to optimize the fertilizer requirement of castor for maximum yield.

Materials and methods

The field experiment was conducted at Research farm of SGCARS, Jagdalpur (Chhattisgarh) during wet season of 2006-07. The soil was sandy loam in texture, high in organic carbon (1.15%), low in available nitrogen (224 kg/ha), phosphorus (14.2 kg/ha) and medium in potassium (281 kg/ha) with pH 5.6. The treatment consisted of 24 combinations comprising 4 levels of nitrogen (0, 40, 80 and 120 kg/ha), 3 levels of phosphorus (0, 30 and 60 kg/ha) and 2 levels of potassium (0 and 30 kg/ha). The experiment was performed in randomized block design with 3 replications. The castor genotype GCH-4 was sown on 11th July. The seeds were manually dibbled by following the spacing of 90 cm between the rows and 45 cm within the rows. The nitrogen (N) was applied in two splits while full dose of phosphorus (P) and potassium (K) was given as basal.

Results and discussion

Application of 80 kg N/ha increased the castor yield significantly over other levels of N (Table 1). The corresponding seed yield under 80 kg N/ha was higher by 13.5, 7.8 and 20.6% over the control, 40 and 120 kg N/ha, respectively. The significant improvement in yield under 80 kg N/ha might be due to more vegetative structure for nutrient absorption, strong sink strength through development of reproductive structures and production of assimilates to fill economic important sink. The results corroborate the findings of Rana et al. (2006).

The increase in seed yield of castor was 13.6 and 7.8% with 30 and 60 kg P_2O_5/ha over the control, respectively. The difference in yield between 30 and 60 kg P_2O_5/ha levels were not significant (Table 1). The increase in seed yield may be attributed to enrichment of soil with P, resulting in its more uptake. The results are in close conformity with the findings of Reddy *et al.* (1999) and Raghavaiah (1999).

Table 1 Effect of nitrogen, phosphorus and potassium on yield of castor under rainfed conditions

Treatment	Yield (kg/ha)
N level (kg/ha)	
0	624
40	657
80	708
120	587
SEm ±	16
CD (P=0.05)	46
P_2O_5 level (kg/ha)	
0	601
30	683
60	648
SEm ±	14
CD (P=0.05)	39
K_2O level (kg/ha)	
0	612
30	676
SEm ±	11
CD (P=0.05)	32

Potassium applied as 30 kg K_2O/ha resulted in significant increase in seed yield over the control. The increase in seed yield was 10.5% than that of the control. This might be because of increase in potassium uptake can be ascribed to the influence of applied K_2O on availability of K_2O in the soil and its extraction by plants as well as concomitant increase in seed yield.

Interaction effect: The interaction effect of N-P_2O_5, N-K_2O and P_2O_5-K_2O had significant effect on seed yield of castor (Table 2). The significant N-P_2O_5 interaction showed that N_{40}- P_{30}, N_{40}-P_{60}, N_{80}-P_{30}, N_{80}-P_{60} and N_{120}-P_0 produced comparable and higher yield as compared to rest of the N-P combinations. The significant interaction between N-K revealed that N_{40}-K_{30}, N_{80}-K_{30} registered significantly higher yield than that of other combinations of N-K. As regards to P_2O_5-K_2O interactions, significantly higher yield was obtained under the interaction between P_0- K_{30}, P_{30}-K_{30} and P_{60}-K_{30} than rest of the other combinations.

Response analysis: Response analysis of N and P_2O_5 showed a quadratic but K_2O showed linear nature for the seed yield. Application of N and P_2O_5 induced a linear increase in the beginning, but with further increase in levels of N and P_2O_5, subsequent decrease in yield, as a result of which, yield recorded quadratic response to N and P_2O_5 application. The quadratic response function of seed yield for applied N and P_2O_5 indicated that physical optimum dose was 56.8 and 36.0 kg/ha to achieve seed yield of 692.2 and 685.4 kg/ha, respectively. Similarly, physical optimum level for applied K_2O was 30 kg/ha for achieving the seed yield of 676 kg/ha.

Table 2 Interaction effect between nitrogen x phosphoru and potassium on castor yield (kg/ha) during 2006-07

N (kg/ha)	P_2O_5 (kg/ha)		
	0	30	60
0	508	665	698
40	541	740	689
80	670	756	698
120	683	572	507
SEm ±		28	
CD (P=0.05)		79	

N (kg/ha)	K_2O (kg/ha)		
	0		30
0	508		665
40	541		740
80	670		756
120	683		572
SEm ±		23	
CD (P=0.05)		64	

P2O5 (kg/ha)	K_2O (kg/ha)		
	0		30
0	546		656
40	701		665
80	589		706
SEm ±		20	
CD (P=0.05)		56	

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Influence of fertility levels on seed yield and its yield attributing characters of pre-release castor varieties

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Abstract

A field experiment was conducted during rainy season, 2008 at JNKVV, Zonal Agricultural Research Station, Chhindwara. The three fertility levels i.e., (40:20:10 N_2: P_2O_5:K_2O kg/ha, 80:40:20 N_2: P_2O_5:K_2O kg/ha and 120:60:30 N_2: P_2O_5:K_2O kg/ha) and five pre-release castor varieties (JC-1, JC-2, DCS-105, DCS-106 and DCS-107 with check 48-1), treatments were laid out in randomized block design in three replication. The response of 120:60:30 N_2: P_2O_5:K_2O kg/ha (3206 kg/ha) recorded significant height seed yield over 80:40:20 N_2: P_2O_5:K_2O kg/ha and 40:20:10 N_2: P_2O_5:K_2O kg/ha. Fertilizer application of 120:60:30, N_2: P_2O_5:K_2O kg/ha accrued higher net returns (46832 Rs/ha)

and B:C ratio (1.97). Among the deferent varieties JC-1 recorded the significantly higher seed yield (3293 kg/ha). The yield of varieties, JC-2 (2896 kg/ha), DCS-105 (2790 kg/ha) and DCS-107 (2760 kg/ha) were at par. The similar trend was noticed in yield attributing characters.

Keywords: Castor, ferrtility levels, pre-released varieties, yield attributing characters

Introduction

Castor is one of the important non edible oil seed crop having export potential in India. India is the largest producer of castor in the world. Castor is the most performed crop for rainfed cultivation. Castor genotype deference in their response to agronomic practices like fertilizer application. The present study is based on response of pre-release castor varieties to nutrient management for improving the production of castor in Madhya Pradesh.

Materials and methods

A field experiment was carried out during Kharif, 2008-09 in vertisol at J.N.K.V.V.; Zonal Agricultural Research Station, Chhindwara. The three fertility levels *viz*- 40:20:10 N_2: P_2O_5:K_2O kg/ha, 80:40:20 N_2: P_2O_5:K_2O kg/ha and 120:60:30, N_2: P_2O_5:K_2O kg/ha and Five pre-release castor varieties JC-1, JC-2, DCS-105, DCS- 106 and DCS-107 with check (48-1), treatments were laid out in randomized block design replicated thrice The experimental soil was clay loam in texture with pH 7.2, 274.0 kg/ha available N, 16.4 kg/ha available P and 412.0 kg/ha available K. Plant spacing of 120 cm x 90 cm for sowing in the experiment. The crop sown on 28th September, 2008. All the recommended practices were followed. Rainfall received 767 mm during the crop season, 2008.

Results and discussion

Seed yield of castor significantly influenced by different fertility levels and genotypes. Among the deferent genotypes JC-1 recorded the significantly higher seed yield (3293 kg/ha). The yield of genotype JC-2 (2896 kg/ha), DCS-105 (2790 kg/ha) and DCS-107 (2760 kg/ha) were at par. Genotype 48-1 (2337 kg/ha) gave less yield than the rest of genotypes resulting in reduced seed yield. Superior performance of JC-1 was due to better plant height (84.0 cm), more no of branch (6.1), more no of spikes/plant (18.5), longer primary spike (64.7 cm), and more 100 seed weight (41.7 g).

Yield attributing characters i.e. plant height, long primary spike, no. of spike, No of braches, 100 seed weight and seed yield increased significantly with successive increase level of fertility over their lower level (table 1). Application of 120:60:30, N_2: P_2O_5:K_2O kg/ha (3206 kg/ha) recorded significantly higher yield over lower levels. The differences among 40:20:10 N_2: P_2O_5:K_2O kg/ha, 80:40:20 N_2: P_2O_5:K_2O kg/ha and 120:60:30, N_2: P_2O_5:K_2O kg/ha were significant with increasing trend 38.5% and 49.8% over 40:20:10 N_2: P_2O_5:K_2O kg/ha in seed yield. Highest value of yield attributing and seed yield with 120:60:30, N_2: P_2O_5:K_2O kg/ha may because of high photosynthesis which resulting in better plant development better, better seed filling and consequently higher seed yield.

Economic analysis of the varieties revealed that JC-1 fallowed by JC-2 and DCS-5 gave higher net return and B:C ratio than the rest of the varieties. With regards to fertilizer application of 120:60:30, N_2: P_2O_5:K_2O kg/ha gave higher net returns (46832 Rs/ha) and B:C ratio (1.97) than the other dose of fertilizer i.e. 80:40:20 N_2: P_2O_5:K_2O kg/ha (42637 Rs /ha and 1.80) and 40:20:10 N_2: P_2O_5:K_2O/ha. (24676 kg /ha and 1.80) resp. ctively.

Table 1 Effect of fertility levels on seed yield and its attributi g charact rs of pre-released castor varieties

Fertility levels N_2:P_2O_5:K_2O kg/ha	Plant Height (cm)	Branche/ plant	Spike per plant	Primary Spike Length (cm)	100 Seed wt (g)	Seed Yield (kg)	Monitory Net Returns Rs/ha	B:C Ratio
40:20:10	55.7	4.2	11.9	43.8	35.0	2139	24674	1.10
80:40:20	75.6	5.7	17.0	53.5	35.9	2963	42637	1.80
120:60:30	83.5	6.8	20.9	58.6	37.1	3206	46832	1.97
SEm+-	2.5	0.34	1.9	2.2	0.23	81	----	----
CD (P=0.05)	7.2	1.18	5.9	5.6	0.61	241	----	----
Varieties								
48-1	79.4	5.4	16.1	42.5	33.8	2337	28537	1.22
JC-1	84.0	6.1	18.5	64.1	41.7	3293	49564	2.13
JC-2	70.0	4.7	12.7	53.8	34.1	2896	40823	1.75
DCS-105	67.1	6.0	18.1	51.5	37.0	2790	38493	1.65
DCS-106	65.0	5.0	17.1	51.3	34.2	2542	33039	1.42
DCS-107	65.4	6.3	17.1	48.5	35.1	2760	37831	1.62
SEm+-	2.1	0.11	1.2	1.9	0.18	56	----	----
CD (P=0.05)	6.0	0.48	3.8	4.9	0.58	156	----	----

Effect of intercropping on seed yield and economics of castor (*Ricinus communis* L.) grown under rainfed conditions

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Abstract

A field experiment was conducted at the National Academy of Agricultural Research Management, Hyderabad during kharif 2007and 2008. Castor variety 'Kranti' was grown in two planting patterns viz., uniform row spacing of 90 cm and paired row spacing of 120/60 cm with a common intra row spacing of 20 cm. They were evaluated in sole and intercropping systems. One row each of sorghum and sunflower and two rows each of pearl millet, green gram, black gram and soybean were flanked between the uniform rows and an additional intercrop row was interspersed between the paired rows of castor. The results showed that the seed yield of castor did not differ significantly by planting the crop in uniform row spacing of 90 cm or paired row planting at 120/60 cm. The intercropping of black gram did not reduce the seed yield of castor. Sorghum, pearl millet, green gram, soybean and sunflower were highly competitive intercrops. They reduced the seed yield of castor. The intercropping of green gram or black gram between the uniform rows of castor were the most lucrative in terms of castor equivalent yield, net returns per hectare, net returns per rupee investment and RNR index.

Keywords: Castor, intercropping, seed yield, economics

Introduction

Castor (*Ricinus communis* L.) is generally grown under extremely neglected conditions in wide rows and in soils of coarse texture and poor fertility status. Wider fluctuations in the amount of rainfall and its distribution received through south-west monsoon during the crop growth period results in wide variation in productivity. The crop has hardy growth habit with deep tap root system. It is a long duration crop with slow growth habit in the initial stages. These features offer a potential scope to intercrop relatively short duration and quick growing crops to exploit the land resources more efficiently. The intercropping of compatible crops is one possible way to minimize the risk of complete loss for sustenance of peasants. Hence a field experiment was conducted to test crops of diverse growth habit by intercropping with castor under rainfed conditions.

Materials and methods

The investigation was carried out at the Agricultural Farm, National Academy of Agricultural Research Management (NAARM), Rajendranagar, Hyderabad. The soil was sandy clay loam in texture, slightly alkaline in reaction, low in available nitrogen (142 N kg ha-1), and phosphorus (9.96 kg P ha-1) and rich in potassium (341 kg K ha-1). The soil had a tendency for crust formation.

The experiment was laid out in randomized block design with three replications. There were 14 treatments. They involved two planting patterns of castor in uniform row spacing of 90 cm and paired row planting at 120/60 cm. Spacing between the plants within the rows was 20 cm in both the planting patterns. Castor variety 'Kranti'was grown as a sole crop in both the patterns and intercropped with sorghum (var.CSV-20), pearl millet (var. ICMV-221), green gram (var.WGG-37), black gram (var. TAU-1), soybean (var. JS-335) and sunflower (var. Morden). One row of sorghum and sunflower but two rows of pearl millet, green gram, black gram, and soybean were intercropped between two rows of castor in uniform row planting. Two rows of sorghum and sunflower and three rows of pearl millet, green gram, black gram and soybean were intercropped between the paired rows of castor. Each of the intercrop was also raised as sole crop in plots adjacent to the experiment for their use in the calculation of land equivalent ratios. There was a rainfall of 361.2 mm distributed in 14 weeks during the crop growing period in 2007. A higher amount of 843.9 mm rainfall was distributed over a period of 11 weeks during the second year. Castor was fertilized with 80:60:40 kg N, P2O5 and K2O / ha in sole and intercropped systems. The intercrops were also fertilized in proportion to their population. All the recommended agronomical practices were followed and crops were raised completely as rainfed. The prevailing market prices of inputs and produce were taken into account for calculating the economics. The castor equivalent yield (CEY) was calculated as follows.

$$CEY = \frac{\text{Yield of intercrop} \times \text{Price of intercrop produce}}{\text{Price of castor produce}} + \text{Yield of castor}$$

Where,

Yield in kg /ha , Price of produce in Rs/kg

The relative net returns index (RNR) proposed for any intercropping system to be compared with the major sole crop was worked out following the approach suggested by Jain and Rao (1980) as,

$$RNR = \frac{(Pi\ Yi + PjYj) \quad Dij}{Pi\ Yii}$$

Where,

Yi and Yj = The yields of ith major crop per hectare and jth intercrop per **hectare on i, jth crop combination**

Pi and Pj = The prices of ith major crop and jth intercrop respectively

Yii = The yield of ith sole crop per hectare and

Dij = The differential cost of cultivation of i, jth crop combination in compar**ison to ith sole crop**

Results and discussion

Seed yield of castor: The seed yield of castor was not affected by intercropping black gram both during 2007 and 2008 (Table 1). But castor produced significantly less seed yield by intercropping sorghum, pearl millet, green gram, soybean or sunflower. The seed yield reduced significantly by the intercropping of sorghum, pearl millet or sunflower consistently during the two years as these crops were highly aggressive to impart severe competition for resources with castor during its reproductive development phase, until it reached physiological maturity. The intercropped black gram grew less vigorous with stunted growth during both the years. Hence black gram did not exert competition for resources with castor. However, intercropped green gram and soybean grew more vigorous and as a result competed with castor for the natural and applied resources and affected its seed yield both during 2007 and 2008. Such drastic competitive effects in reduction of castor yield due to intercropping of sorghum (Patel et al., 1989), and of green gram and soybean (Gupta and Rathore, 1993) were documented in the literature. However, no significant reduction in castor yield due to intercropping with black gram or green gram or soybean was reported by Srilatha et al. (2002). Continuous rains during the vegetative growth stage of crops followed by prolonged dry spells during reproductive stage during the second year severely affected the growth and development of crops and drastically reduced the yields.

Land equivalent ratio: The oft-cited biological efficiency of intercropping systems- the land equivalent ratio (LER) is more *common technique of identifying the relative performance of intercropping systems (Table 2). The LERs recorded 24 to 61%* increased total productivity per unit area over sole castor by intercropping with two rows of black gram, soybean or green gram between the uniform rows of castor during the two years.

Table 1 Seed yield/ha of castor as influenced by planting pattern and intercrops

Treatment	Seed yield (kg / ha)	
	Rainy season, 2007	Rainy season, 2008
Planting pattern		
Uniform rows	625	406
Paired rows	631	415
SE±	23	20
CD (P=0.05)	NS	NS
Intercropping		
Sole castor	897	600
Castor + Sorghum	477	310
Castor + Pearlmillet	338	221
Castor + Greengram	484	435
Castor + Blackgram	878	571
Castor + Soybean	702	432
Castor + Sunflower	620	305
SE±	43	38
CD (P=0.05)	89	78
Interaction		
SE±	61	54
CD (P=0.05)	NS	NS

Economics: The data on economic evaluation of castor in sole and different intercropping systems is presented in table 3. The intercropping of green gram and black gram between uniform rows of castor maximized the net returns per hectare, net returns per rupee investment and the RNR indices during the two years. The intercropping of two rows of black gram or green gram in uniform rows of castor or three rows between the paired rows of castor emerged as statistically superior systems with higher crop equivalent yields than the sole crops during both the years of investigation. Several small farmers do not have the capacity to incur more expenditure to realize maximum yield potential and profit and economic evaluation based on profit. An economic evaluation based on profit realized per rupee investment is more valuable to the small farmers. Incidentally, these two intercropping systems also fetched maximum profits per rupee investment. Higher economic returns compared to the sole castor were also reported by intercropping groundnut, green gram, black gram, cluster bean, soybean or cowpea with castor by Patel et al. (1989), Reddy and Venkateswarlu (1989), Selvaraj et al. (1992), Gupta and Rathore (1993), Rao and Lavanya (2003).

The study confirmed that under divergent conditions of rainfall both in quantity and distribution castor planted in uniform rows at spacing of 90 cm can be efficiently intercropped with two rows of black gram. This will produce bonus yield of the pulse. The intercropping of green gram was also equally profitable.

Table 2 LER as influenced by planting pattern and intercrops

Treatment	Rainy season, 2007	Rainy season, 2008
Uniform row planting		
Castor+Sorghum	1.09	1.00
Castor+Pearlmillet	1.11	1.20
Castor+Greengram	1.40	1.39
Castor+Blackgram	1.61	1.60
Castor+Soybean	1.59	1.24
Castor+Sunflower	1.21	1.03
Paired row planting		
Castor+Sorghum	1.09	1.14
Castor+Pearlmillet	0.90	1.00
Castor+Greengram	1.20	1.29
Castor+Blackgram	1.32	1.36
Castor+Soybean	1.43	1.23
Castor+Sunflower	1.33	1.16

Table 3 Castor equivalent yield and monetary returns as influenced by intercropping

Treatments	Rainy season, 2007				Rainy season, 2008			
	CEY* (Kg/ ha)	Net returns (Rs / ha)	Net returns (Rs / Re)	RNR**	CEY* (Kg/ ha)	Net returns (Rs / ha)	Net returns (Rs / Re)	RNR**
Uniform row planting								
Sole castor	854	11351	1.14	--	586	6391	0.64	--
Castor + Sorghum	571	630	0.04	0.97	361	-3657	-0.24	1.03
Castor + Pearlmillet	897	9705	0.65	1.39	753	8126	0.54	1.78
Castor + Greengram	1179	16464	1.10	1.72	942	12823	0.85	2.09
Castor + Blackgram	1225	16573	1.10	1.72	903	11142	0.74	1.97
Castor + Soybean	900	7594	0.50	1.34	553	450	0.03	1.31
Castor + Sunflower	794	4850	0.32	1.16	541	164	0.01	1.30
Paired row planting								
Sole castor	940	13494	1.35	--	614	7180	0.72	--
Castor + Sorghum	587	1077	0.07	0.89	425	-1815	-0.12	1.05
Castor + Pearlmillet	759	5988	0.40	1.11	642	4950	0.33	1.49
Castor + Greengram	1053	13119	0.87	1.41	891	11287	0.75	1.85
Castor + Blackgram	1081	12894	0.86	1.41	786	7799	0.52	1.63
Castor + Soybean	923	8147	0.53	1.23	601	1748	0.11	1.33
Castor + Sunflower	919	7980	0.53	1.19	621	2391	0.16	1.34
SEm ±	67.99	-	-	0.09	84.50	-	-	0.25
CD (P=0.05)	140.52	-	-	0.18	174.65	-	-	0.53

CEY* = Castor equivalent yield; ** RNR= Relative net returns

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Constraints and strategies for eri-culture through castor and cassava in Chhattisgarh

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Abstract

Eri-culture is practiced at North eastern states, Bihar and Orissa in large scale, but in Chhattisgarh it is new emerging technique for production of silk through feeding of Castar and Cassava leaves. This technique has been introduced during the year 2003-04 under Catalytic Development Programme, sponsored by Central Silk Board in Xth plan. The Eri-silk worm is polyphagous in nature, feeding on a number of food plants namely Castor (*Ricinus* communis).Cassava (*Manihot esculenta* Crantz.) and Kesseru (*Heteropanax fragrance*). Many district of Chhattisgarh like Bastar, Dantewada, Bijapur, Narayanpur, Kanker, Jashpur, Bilaspur, Surguja and Korea are suitable for cultivation of Castar and Cassava/Tapioca. So, in these Districts have lot of possibilities for Eri-culture through Castar and Cassava? In these areas Eri-culture is practiced and promoting by state sericulture Department and Central Silk Board and getting very good success.

Keywords: Constraints and Strategies, Eri-culture, Castor, Cassava

Introduction

Castor plantation is practiced by the farmers in Chhattisgarh state on bunds of agriculture land to protect their crops from cattle, wind, frost etc. and also to earn additional revenue by selling castor seeds. However they are still unknown about eri-silkworm rearing. According to suitability of climate for eri-culture and possibility of adoption of eri-culture on a commercial basis, initially four districts Jagdalpur, Kanker, Jashpur and Surguja of the state have been selected. In the bastar region of chhattisgarh ,at the regional tasar research station (RTRS),Jagdalpur eri-silkworm rearing was successfully conducted by undertaking three crop of castor in different season of the year 2004-2005 (Mahobia et.al 2005).Total 196 acres of castor plantation have been done during the year 2006-07, and beneficiary families were benefited from production of 3659 kg. eri cocoon has been produced during the year 2006-(Chhattisgarh Sericulture news letter 2007).

The geo-eco climatic conditions of Chhattisgarh favor commercial production of all the varieties of natural silks of which eri culture is being given due thrust to supplement the income of castor and tapioca growers through better utilization of leaves without effecting the seed/tuber production (Jayaprakash et al., 2003). In addition, adoption of eri culture provides additional employment for tribal and other poor rural population and contributes to the increased productivity of era-silk in the country. Castor is done only for the production of oil seeds while Tapioca for tuber production. It is well established that 30-40% for foliage from castor/Tapioca plantation can be used for silkworm rearing without effecting the seed/tuber production. The geo-eco climatic conditions of andhra Pradesh favour commercial production of all the varieties of natural silks of which eri culture is being given due thrust to supplement the income of castor and tapioca growers through better utilization of leaves without effecting the seed/tuber production. In addition, adoption of eri culture provides additional employment for tribals and other poor rural populace and contributes to the increased productivity of eri-silk in the country (Jayaprakash et.al-2005). .It is in this contester culture is providing substantial additional income apart from regular earnings to the poor dry land cultivators besides providing gainful employment to the women in zones, the potentiality of eri- culture as a viable subsidiary avocation has been highlighted but many workers. Considering the advantages of eri-culture of the state, the government has initiated various steps to popularize era- culture in the state and also to stabilize this cottage industry through various measures such as production of commercial eri-seed within the seed farms, imparting necessary training in eri-culture technologies, conducting field visits and exposure and create marketing facilities to the farmers etc. In case of castor variety JCR-18 gives highest seed yield (14.21 qt/ha.) and leaf yield (7.8 kg/plant). In case of cassava variety Sree Rekha gives higher tuber yield (460 qt/ha) and variety Sree Vishakham gives highest leaf yield (3.30 kg/plant) observed during experiment and these may be suitable varieties for eri-culture in chhattisgarh. Varieties of Castor and Cassava grown in Chhattisgarh are of short to long duration taking about 250-300 days for maturity and also give more leaf yield for rearing of eri-silk worms or eri-culture during cultivation of castor and cassava. Farmers can produce eri-silk in 3-4 times from the same field and gate additional income with castor seed and cassava tubers.

Results and discussion

Constraints for Eri - culture in Chhattisgarh : In chhattisgarh castor and tapioca are cultivating on a very limited scale. There is a great Scope for area expansion in Chhattisgarh as available varieties in the state for producing eri- silk through feeding their leaves and additional income through castor seed and cassava tubes. There is several eri-silk production constraints encountered by very small acreage of eri- culture in Chhattisgarh.

- Lack of high yielding varieties of Castor and Cassava food Eri-culture.
- Lack of short duration and dense foliage varieties of castor and Cassava.
- Lack of extension work on Eri-culture.
- Castor and cassava is new crop for the farmers of Chhattisgarh.
- Lack of improved Eri silk production and protection technologies.
- Lack of seed production technologies for new varieties of castor and cassava.

In case of castor variety JCR-18 gives highest seed yield (14.21 qt/ha.) and leaf yield (7.8 kg/plant). In case of cassava varieties Sree Rekha gives higher tuber yield (460 qt/ha) and variety Sree Vishakham gives highest leaf yield (3.30 kg/plant).

Marketing: Markets are not easily available whose farmers can sell their produce and they can that proper monetary return of their produce.

Lack of extension work on castor and cassava: There is lack of prompt extension activities for creating interest among the farmers regarding the eri-culture

New technique for the farmers of chhattisgarh: Being a new technique for the farmers of chhattisgarh they are not confident whether this eri-culture profitable is not and that is why like to take risk.

Lack of seed production technologies for new varieties of castor and cassava suitable for eri-culture:

Seed production technologies have not been developed for supply of new varieties of castor and cassava.

Lack of trained farmers for era-culture: Proper training for eri-culture is required for improving the skills of farmers.

Table 1 Suitable varieties of castor and cassava for eri-culture

Crops for Eri-culture	Varieties suitable for Eri-culture	Duration in days	Seed yield for Castor and Tuber yield for Cassava (Qtl/ha.)	Leaf yield (kg/Plant)
Castor	JCR-3	220	9.84	4.50
	JCR-5	180	7.52	5.60
	JCR-17	250	13.53	6.70
	JCR-18	255	14.21	7.80
	Jyoti	150	9.56	5.60
	Jawala	120	11.14	4.50
	Kranthi	150	9.78	4.50
	TMV-5	150	10.00	5.70
	TMV-6	120	9.20	3.40
	Haritha	180	13.20	5.60
Cassava	IGT-1	260-270	350	3.21
	CO-2	260-275	300	3.10
	CO-3	240-270	360	3.12
	MVP-1	270	340	2.90
	H-165	240-270	330	3.25
	H-226	270-300	300	3.20
	Sree Vishakham	270-300	350	3.30
	Sree Sahaya	300	350	3.10
	Sree Prakash	210-240	300	2.80
	SreeVijaya	180-210	180	2.70
	Sree Jaya	180-210	230	2.75
	Sree Rekha	240-300	460	3.13
	Sree Prabha	240-300	420	3.10

Table 2 Prevailing cropping system of castor and cassava in Chhattisgarh

Crop	Cropping system	Farming Situation
Castor	Castor + Chilli	Upland
	Caster + Brinjal/Tomato	
	Castor + Cowpea	
	Castor + Urd	
	Castor + Zinger/Turmeric	
Cassava	Cossava + Cow pea	Upland
	Cossava + Cluster bean	
	Cossava + Cucurbits	
	Cossava + Brinjal /Chilli	

Strategies for enhancing eri-culture in chhattisgarh:

- Adoption of following steps may increase the area and production of castor and cassava for eri-culture in chhattisgarh:
- Development of suitable varieties of castor and cassava for eri-culture.
- Creating marketing facilities.
- Making the eri-culture more remunerative.
- Exploration of improved eri-culture management practices.
- Development of seed production technologies of castor and cassava for the new varieties for eri-culture.

Making eri-culture more remunerative: Exploration of suitable intercrops between castor and cassava rows will make the eri-culture more remunerative. Farmers are interested in growing of castor and cassava intercropped with other crops.

Exploration of improved eri-culture management practices: Improved crop management practices for various agro-climatic conditions should be generated to maximize the castor seed yield and cassava tuber yield with additional leaf yield for eri-silk yield.

Development of seed production technologies for new varieties of castor and cassava specially for eri-culture: Location and suitable specific seed production technologies should be generated for parental lines as well as certified seed specially for eri-culture.

Development of seed production technologies for eri -silk moth (DFL): Disease free egg laying or eri- silk moth (DFL) production technologies should be generated in chhattisgarh since the eri cocoon is non -reliable, only spun yarn can be produced. For eri cocoon spinning CSTRI motorised cum pedal operated spinning machines are being used in chhattisgarh.

Usage of eri pupae: Eri - Eri pupae are a rich source of protein and vitamins. Due to high degree of nutrition the Department is trying to use it as ingredient in fish and poultry feeds fetching additional income to the farmer.

Marketing: To encourage the eri silkworm farmers cocoon banks (Anonymous,, 2007) Purchase eri cocoons at support price of Rs. 30/- per kg (with pupa) and Rs. 180/- per kg (without pupae).

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Effect of atmospheric CO_2 enrichment on castor bean (*Ricinus communis* L.) growth and yield

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Abstract

Climate change is expected to influence the growth and yield potential of all plants including cultivated ones. Elevated carbon dioxide an important component of climate change reported to have positive impact on crop growth and productivity. Growth and yield responses of castor bean (*Ricinus communis* L.)- a non-edible oilseed crop was evaluated in Open top chambers at elevated CO2 concentrations (550ppm and 700ppm) for its response in terms of total biomass, seed yield, oil content and its quality. The growth characters viz., leaf area, the dry weights of different plant parts, leaf area duration and crop growth rate were increased with 550 and 700ppm of CO_2 concentrations as compared with ambient (370ppm) control. The total biomass was highest at 700ppm (22%) followed by 550ppm (11%). The enhanced CO_2 condition also reduced the days to initiation of flowering by three days and days to 50% flowering up to 15 days. A highly significant increase of spike length, pod and seed yield of first order spikes were recorded under increased CO2 levels. At the maturity of first order spikes, the improvement *of the reproductive biomass was by 46% at 700ppm and 35% at 550ppm than ambient level. The results on seed* quality *viz.*, oil content, ricinoleic, palmitic and stearic acids showed similar values at all CO_2 levels. The better response of castor bean to increased CO_2 concentrations is a positive indication for its continued existence in future changed climatic conditions.

Keywords: Castor bean; elevated carbon dioxide; total biomass; yield; quality

Introduction

The atmospheric concentration of carbon dioxide- the most important anthropogenic greenhouse gas increasing at alarming rates (1.9ppm per year) in recent years than the natural growth rate. Since the beginning of the industrial revolution, human activity has the potential to alter biogeochemical cycling and climate patterns through increase in CO_2 and other greenhouse gases in the atmosphere (IPCC 2007). Castor bean (*Ricinus communis* L.) is an indeterminate, non-edible oil seed crop grown in low rainfall regions of semi-arid tropics and sub tropics. Castor is almost entirely grown under dryland conditions. Understanding of physiological responses of castor bean to its environment like an elevated CO_2 levels will be useful in assessing its ability to survive in changed climatic situation and also to improve the crop to fit into the predicted new environment.

Materials and methods

Castor bean (*Ricinus communis* L.) cv DCS-9 crop was raised in open top chambers (OTCs) to study the effect of different levels of CO_2 (700, 550 and 365 ppm) on growth and yield. Two individual chambers were maintained for each CO_2 levels as replicates. The chambers without any external CO_2 supply served as ambient chamber control (Ch-control). The crop was completely rainfed, which received 573 mm in 25 rainy days with reasonably regular intervals. The crop was maintained up to maturation of first order spikes i.e., primaries (105 DAS), as the canopy was too huge to manage in OTCs. Hence, the studies in the present investigation were restricted only up to the maturity of the first order spikes.

Yield measurements of first order spikes were made after harvesting the plants at 105 DAS. Number of capsules, spike length (cm/plant), spike dry weight (g/plant), capsule dry weight (g/plant), seed weight (g/plant) and 100 seed weight were recorded. Total oil content was determined by using Soxhlet apparatus and fatty acid analysis was done by using HPLC. All the data was statistically analyzed using two-way analysis of variance (ANOVA) to determine the significant differences.

Results and discussion

Castor has showed positive response to elevated CO_2 levels in terms of biomass and seed yield (Table 1). At elevated CO_2 levels the leaf area and leaf weight increased during the crop growth period than ambient level. Whereas decreased specific leaf weight resulted thinner leaves with increased levels of CO_2 when compared with ambient condition. Elevated CO_2 stimulate the leaf growth and area 1.7 folds than ambient CO_2 in Ricinus communis (Grimmer *et al.*, 1999).

The results obtained from the present study showed an increase in the dry matter production as well as economic yield at both 550 and 700ppm. Castor is a monoecious plant bearing both male and female flowers on the same spike and the flowering in castor is sensitive to temperature and other stresses. A critical observation of yield components *viz.*, total spike length vs effective spike length revealed a higher female to male ratio at both the elevated CO_2 levels tested. This significant response of castor crop could be due to its better sex ratio conversion from male to female ratio as reported by Vanaja *et al.* 2009. The improvement in effective spike length (12 & 15%), spike weight (46%), capsule number (98 & 65%), capsule weight (46 & 54%) and seed weight (155 & 167%) of primaries was observed with CO_2 enrichment at 550 and 700ppm respectively. Rogers and DahlMann (1993) compiled a synopsis of dry matter production and yield increase of the ten most important crop species in response to elevated CO_2. Their work shows that in some species, there was a relative increase in total biomass and in others, it was economic yield, which was greater.

The oil content in castor showed similar pattern without any significant change at increased levels of CO_2 though the trend was towards the slight decrease i.e from 44.2% in ambient control to 44.1% and 43.8% at 550ppm and 700ppm respectively. The fatty acid composition in castor revealed a high proportion of ricinoleic acid content with 86.21% followed by linoleic acid content of 6.88%, oleic acid with 4.56% and the remaining two fatty acids *viz.*, stearic acid and palmitic acids both with 1.44%. Though ricinoleic acid was similar between ambient control and elevated CO_2 the trend was towards the decremental side, the absolute values were non-significant with 86.43% in ambient control and 86.25% and 85.13% under 550ppm and 700ppm, respectively. Few studies have been conducted to specifically document changes in seed composition caused by climate change like elevated CO_2. Thomas *et al.*, (2003) reported oleic and linolenic acid contents were increased in soybean under elevated CO_2. However no effect of elevated CO2 was observed by Burkey et al., (2007) on protein and oil contents of groundnut seed but there were changes in fatty acid composition.

The results obtained from the present study revealed that elevated levels of atmospheric CO_2 (550 and 700ppm) concentration resulted in an increase in the dry matter production as well as economic yield. However, increase in biomass was more than economic yield when CO2 concentrations increased above 550ppm. Castor has high rate of photosynthetic capacity (Dai *et al.*, 1992), due to this feature it could able to fix extra CO_2 available under enhanced CO_2 conditions and ultimately reflected as increased growth and biomass production. The contribution of first order spike yield to total bean yield in castor will range between 40 to 60%. Due to the developmental plasticity possible in view of the first, second and later order spikes, the yield increment can be expected to be much higher in this indeterminate crop with CO_2 enrichment than what we obtained in the present investigation. These results clearly indicate that castor responded better with increased CO_2 levels alleviating the fears of climate change.

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Table 1 Yield parameters of castor (per plant) at maturity of first order spikes under 550 and 700 ppm CO2 levels and percentage increase over the ambient chamber control. (370 ppm)

Parameters	Treatments		
	700ppm	550ppm	Chamber Control
Total biomass	505.36 (22.01)	461.25 (11.36)	414.18
Vegetative biomass	423.8 (18.15)	386.6 (7.78)	358.7
Reproductive biomass	81.56 (47.01)	74.65 (34.55)	55.48
Primaries			
Spike dry weight (g)	35.7 (46.31)	35.6 (45.90)	24.4
No. of capsules	31.2 (65.08)	37.4 (97.88)	18.9
Capsule dry weight (g)	26.8 (54.02)	25.4 (45.98)	17.4
Seed number	76.17 (150.15)	73.3 (141.02)	30.45
Seed weight (g)	17.9 (167.16)	17.1 (155.22)	6.7
100 seed weight (g)	23.5 (6.82)	23.3 (5.91)	22.0

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