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Review Article

Genetically engineered systems of male sterility

S.K. Banga, P.B. Bhaskar and S.S. Banga

Department of Plant Breeding, Genetics & Biotechnology, Punjab Agricultural University, Ludhiana-141 004, Punjab

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Abstract

Success to genetically engineer nuclear encoded male sterility by subtle modifications in key developmental processes during microsporogenesis has allowed new options of pollination control for hybrid seed production in hermaphrodite crops. Different strategies evolved to achieve male sterile phenotype include stage specific expression of cytotoxic genes (e.g. barnase), aberrant tapetal function, modification of biochemical pathways (e.g. jasmonic acid synthesis), antisense inhibition of essential gene products or impaired mitochondrial function. Insertion of chimaeric transgenes, driven by anther specific promoters, has ensured a male tissue specific expression. Propagation of male sterile lines in many of these approaches is simple since foliar application of suppressed metabolite can reverse male sterility expression and permit self seed set which results in pure male sterile progeny. Some of these systems also offer the possibility of inducible male sterility which can be triggered by expressing a gene encoding a protein which catalyzes the conversion of a pre-herbicide into herbicide only in the male gametophyte. Rapeseed hybrids based on barnase-barstar system are now commercially available and this nuclear encoded transgenic male sterility has already been engineered in many crops, including wheat and maize.

Key words: Genetically engineered system, male sterility, barnase-barstar, hybrid

Introduction

Commercial exploitation of hybrid vigour in hermaphrodite crops is facilitated by the availability of CMS lines to effect pollination control. As the CMS genotype results from alloplasmic substitutions or by harnessing the mitochondrial mutations, they are generally associated with yield penalty and imperfect fertility restoration in the hybrids. These imperfections in CMS-fertility restorer systems have stimulated considerable research effort to engineer new and perhaps more efficient male sterility systems (Kaul, 1998; Perez-Prat and van Lookeren Campagne, 2002). Most of these efforts take advantage of the fact that microsporogenesis is a complex developmental process sensitive to mutations. Disruption of any of the steps of microsporogenesis or its premature termination results in male sterility. Male sterile plants have been produced by aberrant spatial or temporal expression of degrading enzymes or through inhibition of specific enzymes via antisense strategy. In the present write up an attempt has been made to review current realities and emerging possibilities in the arena of genetically engineered male sterility in crop plants.

Cell Cytotoxicity

Barnase - barstar : one component system: The first success in developing genetically engineered male sterility in crop plants was through inserting chimaeric dominant gene *barnase* (bacterial *RNase*) driven by a tapetum-specific promoter (*TA 29*) in tobacco and rapeseed. The anther-specific promoter *TA 29* was fused with *barnase* (RNase) gene from *Bacillus amyloliquefaciens* to construct *TA29-barnase* chimaeric gene (Mariani *et al.*, 1990) and introduced into tobacco and oilseed rape plants. About 92% of the *TA29-barnase* transformants failed to shed pollen and were completely male sterile whereas female fertility was normal. Further studies revealed that the *TA29* programmed the expression of the *barnase* gene specifically to anther tapetal cells, which caused premature selective ablation of the tapetal cell layer that surrounds the pollen sac, presumably by hydrolyzing the tapetal cells. This disrupted the normal pollen formation and caused male sterility. Male sterile flowers showed noticeable reduction in length of stamen filament, petal size, reduction in bud diameter, and tapetal cell content. Sterile anthers contained empty exines.

To restore fertility, the pollen parents were transformed with *barstar* gene (*RNase* inhibitor) from same bacterium (Mariani *et al.*, 1992). Upon crossing barnase male sterile plants with transgenic fertile plants carrying *TA29-barstar* chimaeric gene, the F_1 progeny showed coexpression of both the genes in the anthers of the male fertile plant. It was found that *barstar* gene is dominant to the *barnase* gene, and fertility restoration was due to the formation of tapetal cell-specific *barnase-barstar* complex inhibiting the

expression of *barnase* gene. Female fertility was not affected, and transformed plants had normal morphology. By coupling the *TA29-barnase* gene to a dominant herbicide resistance "Bar" gene, uniform populations of male sterile plants could be produced. *"Bar" gene confers* resistance to the herbicide *bialophos* (phosphinothricin or PPT) and is used as a marker for male sterility (Denis *et al.*, 1993). Transgenic male sterile plants of *Brassica napus* variety Drakkar were linked to the *"Bar"* gene coding for PPT acetyl transferase and were resistant to herbicide PPT. Maintenance progeny showed 50 % plants that were male fertile but susceptible to the herbicides. Application of PPT permitted the elimination of male fertile susceptible segregants in the field by herbicidal application and assured 100 % production of hybrid seed on male sterile plants.

The *barnase-barstar* male sterility-fertility restoration system is now also available in chicory, cauliflower, tomato, cotton, corn and in wheat (Banga and Raman 1998). Reversion to fertility from male sterile plants has been observed in some cases. Jagannath *et al.* (2001) could develop stable transgenics by using gene constructs having spacer DNA in between the barnase gene and the *CaMV 35S* promoter-driven *bar* gene. The newly developed male sterile lines, however, could not be restored by transgenics carrying wild type barstar. To restore fertility in such male sterile lines modified barstar constructs were developed (*Jagannath et al., 2002*).

Barnase : two *component* system: Incomplete elimination of male fertile segregants from female line in hybrid seed production plots and the necessity of using two transgenic lines for synthesis of hybrid is a major limitation of barnase-barstar system. To overcome these, a two component system of barnase induced cell lethality has been developed (Burgess *et al.*, 2002). This involves engineering extracellular ribonuclease, into two complementary fragments, the N-terminal and the C-terminal peptides. The DNA encoding modified N-terminal and C-terminal barnase peptides were cloned and fused separately with a tapetal-specific promoter 127a from tomato to generate chimaeric gene constructs, p127a-Bn 5-2 and p127a-Bn 3-2. Their separate deployment in tomato resulted in two lines, one transgenic for p127a : Bn 5-2 and other transgenic for p127a : Bn 3-2. The insertion of these transgenes at allelic position was achieved by using a site-specific recombinase such as Cre-recombinase to independently insert both the transgenes into a pre-existing lox site (Ow and Medberry, 1995). Male sterility resulted when these two independently derived male fertile lines were crossed. This two component male sterility system is robust to temperature variation and also allows pure stands of male steriles to be generated. This is in contrast to traditional barnase system, where only half the progeny (MS/-x-/-) is male sterile, requiring a herbicide resistance gene to be linked to the male sterility transgene to cull out the 50 percent male fertile progeny. Another advantage of this system is that fertility will be restored whenever the male sterile inbred is crossed to any non-engineered pollen parent since both the alleles (Bn 5-2 and Bn 3-2) will be separated during gametogenesis. In contrast, the one component barnase system requires transforming the pollen parent with a ribonuclease - inhibitor gene, barstar to develop fertile F_1 hybrid. Major limitation of this system is the necessity of some pollination control mechanism to hybridize the two self fertile lines for producing male sterile female parent.

Hormone Engineering

Drastic changes in endogenous levels of auxins cause male sterility in tomato (Sawhney, 1974) and many other crops. Induction of male sterility by genetically manipulating endogenous hormone levels has been demonstrated in transformed tobacco plants carrying *"rol c"* gene of *Agrobacterium rhizogenes* under the control of 35 S *CaMV* promoter and flanked with a marker gene (Spena *et al.*, 1987; Schmulling *et al.*, 1988). Such male steriles can be maintained by linking the gene for herbicide resistance to the male sterilizing *"rol c"*. Male fertile segregants can be chemically rogued out by selective elimination in the maintainer population.

In another experiment, Spena *et al.* (1992) used the tissue specific promoter *"tap I"* and found that the inserted gene *"rol b" from A. rhizogenes*, greatly impaired the flower development in transgenic tobacco due to an increase in the levels of indol acetic acid and decreased levels of gibberellins in anthers.

***Glucanase* : Altered Temporal Expression**

Pathogenesis-related (PR) protein β-1,3 glucanase (callase) is known to dissolve specific cell wall made of callose. The callase secreted by the tapetum helps to release free microspores into locular space by breaking down the callose wall. The genetic alteration of this mechanism in plants leads to male sterility. Worral *et al.* (1992) reported that the transgenic tobacco plants expressing β-1,3 glucanase gene regulated by tapetum-specific promoters *A3* and *A9* showed premature dissolution of microsporocyte callose wall, causing moderate to complete male sterility. Callose appearance and distribution was normal in male sterile transgenic plants up to prophase I, whereupon the callose wall surrounding each microspore dissolved. The premature dissolution of callose indicated that the modified glucanase is secreted from the tapetum and is active within the anther locule. Transgenic tobacco plants expressing the β-1,3 glucanase under the control of CaMV 35S promoter showed normal fertility despite the expression of modified glucanase. This was attributed to either lower expression

of the modified gene in the tapetum or inappropriate timing of the modified callose synthesis during the process of microsporogenesis.

Inducible Male Sterility

Theoretically, it is feasible to genetically engineer plants with pollen exhibiting self-destructive mechanisms. To achieve this, McCormick *et al.* (1989) and Wood (1990) developed transgenics carrying a chimaeric gene consisting of pollen-specific promoter (*LAT 59*) and a gene (*fms 2*) that converts indole acetamide (IAM) into indole acetic acid (IAA). The transgenic plants carrying *LAT59-fms2* gene when sprayed with IAM selectively convert IAM into IAA at very high concentrations to kill the pollen. As the plants are normally fertile in the absence of IAM application, problem of maintenance of male steriles and the restoration of fertility in F_1 hybrids are not encountered. However the complications normally associated with the application of chemical hybridizing agents will remain necessitating spraying of gametocides/CHAs repeatedly at a specific growth stage and interval.

Another possibility of inducing such male sterility is the transformation of plants with chimaeric gene involving *TA29* promoter and coding region of β-glucuronidase (GUS). The *TA29-GUS* transformants, when sprayed with protoxins like sulfonylurea or maleic hydrazide, cause male sterility through their breakdown in the tapetum by the b-glucuronidase enzyme. The transgenic plants not sprayed with protoxins remained fertile, so a fertility restoration system like *TA 29*-barstar is not required. Still another attempt involved inducible destruction of plant tissues based on deacylation of non-toxic compound N-acetyl-phosphinothricine (N-ac-pt), an amino acid analogue and herbicide derivative that carries an acetyl group. This system is based on *argE* gene product (N-acetyl-L-ornithine deacetylase) of *E. coli*, which converts the nontoxic N-ac-pt into the herbicide phosphinothricine by deacetylation mechanism (Kriete *et al.*, 1996). Transgenic tobacco plants carrying a chimaeric gene consisting of tapetum specific TA 29 promoter tagged to *argE* coding region failed to produce pollen grains when sprayed with N-ac-pt whereas untreated plants were normal.

Metabolite Alteration or Suppression

Flavonoids: Flavonoids are the most important and common of three major flower pigments namely, flavonoids, carotenoids and betalains. Aside role in colour development, flavonoids are important in plant reproduction and defence-related processes. In legumes, they may act as signal molecules in interaction with nitrogen-fixing bacteria. The biochemical pathways of flavonoid synthesis have shown that these are produced as phenyl-propanoid based secondary metabolities via chalcone synthase (*Chs*). A large number of genes involved in the biochemical pathway of flavonoid synthesis have been cloned and characterized (Forkmann, 1991). Such cloned genes were used to manipulate flower colour by antisense formation in *Petunia*, *Solanum* and *Nicotiana* flowers (van der Krol *et al.*,1988). To study the possible role of flavonoids in anther development, van der Meer *et al.* (1992) down regulated flavonoid synthesis in the tapetum by using engineered *CaMV 35S* promoter having one, two or eight copies of *Chs-anther box*, a homologous sequence present in the flavonoid- specific gene, active during early stages of anther development. The modified promoter directed the antisense *Chs* expression in tapetum cells and down regulated the pigmentation in anthers of transgenic tobacco. This arrested male gametophyte development and caused male sterility.

Transgenic tobacco plants had white pollen and were male sterile. This pointed to undescribed function for flavonoids during male gametogenesis, although possibility of accumulation of precursors like coumaric acid or caffeic acid was not excluded. The finding suggested that *chs* genes can be engineered to alter biochemical pathways to develop an alternate male sterility technique. Studies in maize and petunia (Taylor, 1995) have shown that pollen lacking flavonols is unable to produce functional pollen tube, but this defect can be reversed, and pollen can function normally by timely application of kaempferol, a flavonol aglycone.

Jasmonic acid : Jasmonic acid (JA), synthesized from linolenic acid (LA) through octadecanoid pathway (Weiler, 1997), plays an important role in anther dehiscence and pollen maturation (Sanders et al., 2000; Stintzi and Browse, 2000; Ishiguro *et al.*, 2001). The triple *fad* (*fad3, fad7, fad8*) mutants lacking LA had indehiscent anthers and hence showed functional male sterility (Mc Conn and Browse, 1996). Recently, Ishiguro *et al.* (2001) linked impaired dehiscence in Defective Anther Dehiscence I (*DAD I*) mutant (Sanders *et al.*, 2000; Stintzi and Browse, 2000) to mutation in *DAD I* gene that encoded a chloroplastic phospholipase A1 to supply free LA at the initial step in JA biosynthesis, they further suggested that JA also regulated flower opening, anther dehiscence as well as pollen maturation. Exogenous application of JA reversed the impaired dehiscence. Based on this Hatakeyama *et al.* (2003) isolated *Br DAD I* from *B. rapa* by utilizing *DAD I* coding region from *Arabidopsis* as a probe. A tandem repeated antisense *Br DAD I* driven by the putative promoter region of *Br DAD I* was constructed and inserted into *B. rapa*. Of the 25 transgenic plants obtained, 3 showed delayed anther dehiscence and inviable pollen. Segregation of the transgene in the selfed progeny was consistent with the Mendelian inheritance of two copies of the transgene at different loci. The male sterile phenotype could be reversed by application of JA (0.5mM) as well as LA.

Genetic male sterility based on *Br DAD I* gene has many advantages; most important being the ability to induce normal pollen production and dehiscence. This is critical for developing lines homozygous for the male sterilizing allele. Moreover, this system involves suppression of a single gene and floral morphology is not adversely affected. The stability of expression over a range of environmental conditions, however, remains to be investigated.

Allene oxide synthase

Allene oxide synthase (AOS), a cytochrome P 450 enzyme (*CYP74A*), commits 13-(*S*)-hydroperoxy linolenic acid to the formation of jasmonates by catalyzing the dehydration of this substrate to 12, 13-epoxy-linolenic acid (allene oxide). PCR-based reverse genetics screening method with CYP 74A- and T-DNA border specific primers on DNA from a large number of T-DNA insertion lines helped in isolation of a knock-out mutant defective in the JA biosynthetic gene *CYP74A* (Park *et al.*, 2002). This *Arabidopsis aos* mutant showed severe male sterility due to defects in the anther and pollen development. F_1 between the knock out mutant and the wild type was fertile and F_2 progeny segregated 3:1, indicating a single T-DNA insertion. The male sterility in the *aos* mutant was rescued by MeJA treatment. Complete male fertility was restored in the treated plants. All the selfed progeny of the *aos* mutant showed male sterile phenotype, confirming that they were selfed progeny of *aos* mutant.

Alternative oxidase

The terminal oxidase, also known as alternative oxidase, of cyanide - insensitive respiratory pathway (CIRP) is known to show higher and tissue specific expression in pollen and tapetum during anther development (Johnes *et al.*, 1993). Its localization in sporogenous tissues of anthers at the premeiotic and meiotic stage as well as in the developing tetrads and the degenerating sporogenous tissues of anthers in petunia has been demonstrated (Conley and Hanson, 1994). Inhibitors of the CIRP such as salicylhydroxamic acid (SHAM) reduced the number of fertile pollen grains when applied on broccoli (Kishitani and Konno, 1990). Based on these, Kitashiba *et al.*, (1999) produced the transgenic plants with antisense alternative oxidase genomic DNA under the control of tapetum specific promoter. Introduction of this alternative oxidase gene under the control of *Ocg6B* promoter into tobacco generated transgenic tobacco plants with reduced pollen viability. Decreased alternative oxidase protein in tapetum of transgenic plants resulted in its premature degeneration, impaired carbon metabolism and electron flow in tapetum cells. The antisense construct used in the studies included alternative oxidase gene of *A. thaliana* and hence may be useful in producing male sterile plants for *Brassica* oilseeds.

Phosphoethanolamine N-Methyl transferase

Choline (cho) is a key metabolite to synthesize the major plant membrane lipid phosphotidyl choline (PC), which accounts for 40-60% of lipids in nonplastid plant membranes. The enzyme S-adenosyl-l-methionine: phosphoethanolamine N-methyltransferase (PEAMT; EC 2.1.1.103) catalyses the key step N-methylation of phosphoethanolamine in choline biosynthesis. Silencing of *PEAMT* gene, using a new sense/antisense RNA expression system (*SARE*) resulted in an *Arabidopsis* mutant, *t 365*, which showed temperature sensitive male sterility (Mau *et al.*, 2002). When grown at low temperature, such as 20°C, *t 365* mutant plants are fertile and produced seeds. However, at temperatures greater than 23°C, the mutant plants were male sterile and produced no seeds in the abnormal siliques. Evidently, silencing of *PEAMT* may provide an efficient tool to engineer temperature sensitive male sterility in key agricultural crops.

Carbohydrates

Carbohydrates play a critical role in the anther and pollen development by sustaining growth as well as signal pathways. Their transportation from photosynthetically active source tissues to developing sinks is regulated by extracellular invertases. This class of invertases are encoded by small gene families with differential regulation and expression patterns. The extracellular invertase *Nin 88* of tobacco shows specific temporal and spatial expression patterns in developing anthers. At early stages of flower development, this invertase is present exclusively in the tapetum cell layers of the anthers followed by a distinct expression pattern during pollen development. The tissue specific antisense repression of *Nin 88* under the control of corresponding promoter in tobacco caused male sterility by blocking pollen development during early stages of microsporogenesis (Goetz *et al.*, 2001). Exogenous supply of carbohydrates in an *in vitro* maturation assay was able to partially overcome this block, thus opening up the possibility of maintaining this male sterility system. Fertility restoration, essential for its use in hybrid seed production, can theoretically be achieved by crossing this GMS system with transgenic plants expressing distantly related invertase (may be from bacteria), which is not under the control of the antisense repression through a plant invertase. Alternatively introduction of a sucrose transporter could bypass the requirement for extracellular sucrose cleavage. Male sterility caused by antisense expression of *Nin 88* was not associated with any morphophysiological abnormality.

Suppression of Essential Genes

Bcp 1

The existence of sporophytic genes controlling male sterility is well documented. Such genes cause male sterile expression by disrupting functioning in parental sporophytic

tissues. Evidence is also now available for gametophytic gene(s) controlling male fertility (Mc Cormick, 1993). *LAT52* from tomato is one such gene. Another class of these gene(s) is anther-specific gene *Bcp1* from *Brassica rapa*, which shows a unique pattern of expression in both diploid tapetum and haploid microspores (Theerakulpisut *et al.*, 1991). The gametophytic as well as sporophytic activity of this gene was observed from in-situ hybridization studies with anther sections of *Arabidopsis thaliana*, which revealed *Bcp1* mRNA in both diploid tapetum and haploid microspores (Xu *et al.*, 1995). *Bcp1* expression in tapetal cells initiated shortly after microspore formation and continued until tapetum degeneration. In unicellular microspores the activity was first detected in the late vacuolate stage. High level of transcript was present in mature and germinating pollen. To confirm the role of *Bcp1* in fertility control, *LAT52* promoter from pollen-specific tomato gene was fused to 0.5kb of a *Bcp1* cDNA insert in reverse orientation and cloned into pB 1101. The second antisense construct was developed by fusion of 0.77kb of a *Bcp1* gene regulatory region with 0.5kb of an antisense *Bcp1* construct. The resulting antisense constructs were subsequently introduced into *Arabidopsis thaliana* via two separate *Agrobacterium tumefaciens* transformation events. Of the 42 primary transgenic (T_o) plants obtained, 16 were completely male sterile. The anthers of transformants carrying *LAT52* (pollen-specific) promoter fused to a reverse *Bcp1* cDNA construct had 1:1 segregation of viable/aborted pollen, suggesting gametophytic male fertility control. Complete male sterility and the absence of typical 1:1 segregation of fertile and sterile pollens in the anthers of transgenic plants carrying *Bcp1* promoter suggested that sterility was the result of down regulating *Bcp1* gene expression in the diploid tapetum. Further genetic studies revealed cosegregation of the male sterile phenotype and the presence of antisense insert. Two copies of the antisense transgene were needed to ensure complete male sterile phenotype. The male sterility system based on *Bcp1* promoter- antisense technology, and linked to a hormone-inducible promoter is now ready for use in hybrid seed production in *B. oleracea*.

AtMYB26

Screening of a *Arabidopsis thaliana* population transformed with maize transposon En-1 / Spm, resulted in identification of male sterile mutant, *myb 26-2* (Lange-Steiner *et al.*, 2003). The male sterility was expressed as indehiscent anthers. Mutant plants produced normal seed set following cross pollination. Mechanical release of pollen grains and their use for self-pollination resulted in completely male sterile progeny. Failure of dehiscence was associated with defects in anther development. Whereas in the wild-type the endothecium cells appeared swollen and showed deposition of lignified cellulosic secondary wall thickenings, in mutant *myb26-2*, these cell wall fortifications were missing and endothecium cells did not expand. Male sterile phenotype was caused by transposon insertion in *AtMYB26* disrupting a putative DNA-binding domain of this R2R3-type MYB transcription factor. The expression of *AtMYB26* was restricted to inflorescence only. High stability of male sterile phenotype, coupled with functional pollen grains, suggested tremendous significance of *AtMYB26* and its orthologs for hybrid seed production.

Impaired Mitochondrial Function

Male sterility mainly results from chimaeric mitochondrial genes and synthesis of new protein (Dewey *et al.*, 1986; Levings and Lersten, 1990). Expression of transgene containing the unedited *atp9* mitochondrial gene (*U-atp9*) fused to yeast *cox IV* presequence caused aberrant tapetal development and consequently the male sterility in tobacco plants (Hernould *et al.*, 1998). The female fertility was normal. Mitochondria of the tapetum cells were severely degenerated, showing loss of cristae and swelling. The mitochondrial modifications resulted from the presence of the transcript and translated products of the unedited *atp 9* and a significant decrease in oxygen consumption in non-photosynthetic tissues. Restoration of fertility in transgenic plants was obtained by crossing male sterile plants carrying the "unedited" mRNA with plants carrying the same RNA but in the antisense orientation (Araya *et al.*, 1994). Such hybridization led to the formation of ds RNA. The ds RNA is a substrate of an unbiquitous enzyme, the RNase III. Resulted cleavage of ds RNA leads to the male fertile phenotype.

Male sterility could also be induced through impaired mitochondrial function using antisense technology. Yui *et al.* (2003) attempted to block anther development in sugarbeet by antisense expression of the mitochondrial *PDH_E1α* gene in tapetal cells. *PDH_E1α* gene encodes pyruvate dehydrogenase (E1 component). The transgenic sugarbeet plants carrying antisense PDH_E1α showed significantly reduced levels of the endogenous *PDH_E1α* mRNA and exhibited male sterility. The male sterility phenotype cosegregated with male sterility in T_1 progeny, indicating that it is the result of *PDH_E1α* antisense RNA expression. Male sterility resulted from hypertrophy and vacuolation of tapetal cells, which invariably preceded the failure of pollen development.

In CMS common bean, a novel mitochondrion DNA sequence (*PVS*) is associated with male sterility. The 3.7 Kb *PVS* sequence contains at least two open reading frames *orf 239* and *orf 98*. Protein product of *orf 239* is present only in reproductive issue indicating it to be responsible for male sterility. The protein product localizes to the callose layer and primary cell wall of developing pollen leading to incomplete cytokinesis resulting in pollen sterility. He *et al.* (1996) introduced this CMS-associated mitochondrion DNA sequence *orf 239* into tobacco nuclear genome. Several transformants exhibited the semi-sterile

or male-sterile phenotype, and the *orf* 239 protein was found associated to the cell wall of developing microspores as observed in CMS-common bean. *Orf 239 represents the* only currently known plant mitochondrially encoded protein that is located outside the mitochondria and is apparently biologically active in interactions with cellular components other than mitochondrion.

Outlook

Despite many questions regarding the stability of transgene expression, threat of unwanted transgene dispersal or multiplication of engineered male sterile plants, the genetically engineered nuclear encoded pollination control mechanisms are of significant agricultural importance for the production of F_1 hybrids. Though the barnase barstar system has already reached the stage of *commercialization*, the real gains will acrue once the systems that rely on chemical regulation of gene expression become available. Growing commercial interest in engineered male sterility is apparent from the increasing number of patents (Fabijanski *et al.*, 1995; Goff *et al.*, 1999; Cigan *et al.*, 2000; Bridges *et al.*, 2001) being granted to protect new innovations. These inventions offer sterility systems with more subtle but efficient modifications in plant metabolic processes as well as the ease of fertility restoration.

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Review Article

Intercropping systems involving castor in India - A review

S.N. Sudhakara Babu and K.V. Padmaja

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP

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Abstract

Intercropping is the traditional cropping system practiced in rainfed regions mainly to safeguard the risk involved in sole cropping. Castor (*Ricinus communis* L.) is one of the ancient and important non-edible oilseed crops that has great industrial and medicinal value. Castor is grown both as a sole crop and as a mixed crop/intercrop and is ideally suited for intercropping systems. It is grown with wide range of crops including cereals, pulses, oilseeds, agro-forestry systems and even as shade crop in plantations that vary in growth, duration, agro-ecological needs, etc. In traditional areas, castor will form the base crop while in non-traditional areas, castor will form a component crop with major crops of the region. The productivity of castor in intercropping systems depends on crop combinations, row ratios, management/rainfall pattern, moisture and nutrient management, pest incidence, etc. In general, sole castor has been highly productive and profitable under stress free situations. Castor offers yield stability in intercropping systems both under high as well as low rainfall years. Land equivalent ratios (LER) of intercropping systems involving castor are higher besides offering selective pest control in selected combinations.

Key words: Intercropping, castor, crop compatibility, LER, pest incidence, stability

Introduction

Castor (*Ricinus communis* L.) is one of the ancient and important non-edible oilseed crops that has great industrial and medicinal value. India is the principal producer of castor, has an area of 7.3 lakh ha and produces of 8.0 lakh tonnes (Damodaram and Hegde, 2005). Gujarat and Andhra Pradesh are the major castor growing states contributing about 40% each of area under castor. Gujarat accounts for 67% of castor production. The productivity of castor is highest in Gujarat and Rajasthan, and lowest in Andhra Pradesh due to the contrasting ecological optimum conditions under which the crop is grown.

Castor is grown both as a sole crop and as a mixed crop/intercrop. However, it is ideally suited for intercropping systems by virtue of its drought tolerance, perenniating nature, branching habit and indeterminate phenology (Trenbath, 1986; Hegde and Sudhakara Babu, 2002; Anjani *et al.*, 2002,). In traditional areas, castor will form the base crop while in non-traditional areas, It will form a component crop with major crops of the region. Patel (1985) documented intercropping systems with castor in the country. In Andhra Pradesh, castor is sown mixed with sorghum, pearl millet, groundnut, finger millet and beans. In Karnataka, castor is mixed with chillies, finger millet and dolichos beans. In Gujarat, pearl millet, sorghum, cotton, groundnut and sesame are the common mixed crops. Its use as wind break is also practiced by sugarcane farmers. In Tamil Nadu castor is grown mixed with groundnut and cotton. Castor is raised as a shade crop in chillies and turmeric and as border crop of sugarcane (Rao *et al.*, 2003). In traditional systems, castor seed is usually sprinkled with major crops and therefore proportion of castor to be sown with other crops is always indefinite.

Crop Compatibility

Dayal and Reddy (1991) found that groundnut yields were highest in pure stands and decreased by intercrops in the order castor, sunflower and sesame at Junagadh. Total oil yield and economic return were increased by intercropping, on average, by 30.5 and 15.3%, respectively. The castor equivalent seed yield, land equivalent ratio (LER) and net returns were highest when castor was intercropped with green gram, and lowest when soybeans were grown alone in Rajasthan (Gupta and Rathore, 1993).

At Tirupati, seed/grain yields of groundnut, castor, sorghum, *Elusine coracana and Setaria italica* were 0.56-0.61,0.86-0.88, 2.67-3.18, 1.13-1.32 and 0.83-1.48 t/ha, respectively, when grown alone and 0.34-0.36, 0.22-0.25, 1.97-2.08, 0.34-1.03 and 0.43-0.69 t/ha when intercropped. The highest pigeonpea equivalent yield (1.81 t/ha) and net returns were obtained when pigeonpeas were intercropped with sorghum (Reddy *et al.*, 1993). Castor + cluster bean [*Cyamopsis tetragonoloba*] (1:2) and clusterbean + sunflower (1:1) intercropping systems were more profitable with soil depths of 10-20 cm, whereas sorghum + pigeonpea (2:1) required soils deeper than 25 cm for good results Katyal *et al.*, (1995). Rajput and Shrivastava (1996) reported that in Madhya Pradesh, castor intercropped with pigeon pea produced the highest castor equivalent yield and the highest net return.

At Tindivanam, castor was evaluated as a component crop in various legume and non-legume crops in 6:1 and 10:1 row ratios. Castor was found to be compatible with all the base crops tried *viz*., blackgram, greengram, groundnut, sunflower and ragi (*Elusine coracana*) giving LER values of more than 1.50. Blackgram + castor system at 6:1 row ratios gave the highest LER of 1.85 with highest yield of castor (Anon., 1993). At Palem (Anon., 1993), pigeonpea, sunflower and cowpea were found to be compatible crops for castor while sesame was found to affect castor crop which gave the LER value of less than unity (0.92). At Mandor (Anon., 1989), castor + green gram system gave highest castor equivalent seed yield (2059 kg/ha) and highest system gross returns (Rs.12443/ha), with a LER of 1.33. Whereas, the LER was highest with castor + groundnut system (1.60).

Castor yields were found to be higher when intercropped with green gram and cluster bean while its yield reduced with sesame (Anon., 1988, 1990), sorghum or green gram. In terms of gross returns, all intercropping systems with castor gave higher returns compared to sole castor under both irrigated and rainfed situations at Mandore (Anon., 1988; 1990). However, the magnitude of yields and returns were lower in rainfed system. Intercropping clusterbeans for seed purpose with castor either in 1:1 or 2:2 ratio was not compatible as the castor yields declined due to the longer period of competition (Venkateswarlu, 1987). In Rajasthan, castor was compatible associate crop with moth bean and pearl millet. The seed yield of castor was considered as a bonus as the main crop was least affected (Hanumantha Rao and Chakrabarthy, 1997).

Sole cropping was more profitable under irrigated conditions compared to intercropping with oilseeds and pulses in North Gujarat (Patel *et al*., 2002).

Shankaraiah *et al*., (1987) evaluated different crops (maize, okra, castor, chilli pepper) as intercrops with turmeric in a 3-year experiment in Andhra Pradesh, and reported that out of the 4 intercrops studied only maize and chilli pepper gave high yields and a high gross income. Turmeric in combination with maize recorded the highest income per hectare, followed by intercropping with chilli pepper. Intercropping two rows of either french bean or dolichos bean provided bonus yield, higher LER and net returns without significantly affecting castor productivity. Though castor yield was affected due to intercropping with carrot, it more than compensated in terms of castor equivalent yield, LER and economics (Veeranna *et al*., 2004).

Crop Geometry

Castor plant has wide plasticity to adapt to wide spacing by way of adjustment in branching. In areas where castor is a major crop, the row spacings can be widened to the extent of 150 cm without any loss in seed yield (Bhaskar Rao and Vijayalakshmi, 1985). Short duration pluses and oilseeds can be effectively grown as intercrops in these wide rows. Intercropping of castor + cowpea, castor + *Setaria*, castor + greengram and castor + cluster bean (vegetable) in the ratio of 1:1 or 1:2 were found to be efficient (Hanumantha Rao *et al*., 1975, 1988; Singh, 1988, Anon., 1989; 1991). Shaik Mohammad *et al*., (1987) inferred that spacing of castor can be advantageously manipulated to 120 x 15 cm to accommodate companion crop. Seed yield of castor under intercropping increased with increasing row width. Sorghum as intercrop reduced the yield of castor drastically at 60 x 30 cm spacing. While at 120 x 15 cm spacing, intercropping system gave higher returns. Desai and Goyal (1980) obtained a cost-benefit ratio of 1:2.63 in castor + sesame (1:1) intercropping. Reddy and Venkateswarlu (1989) studied the fertilizer and planting pattern and found that Intercropping reduced castor and cluster bean yield by 20% and 70%, respectively, compared with sole cropping. Intercropping 1 row of cluster bean between single rows (90 cm apart) of castor gave the highest cluster bean green pod yield of 2.22 t/ha. 10 kg/ha N and 20 kg/ha P_2O_5 applied to cluster bean, significantly increased green pod yield by 38%. There was no effect of different fertilizer applications to cluster bean on castor yields. Reddy *et al*., (1987) found that castor var. Aruna and the hybrid GAUC spaced at 120 x 15 cm yielded 31.5 and 7% less, respectively, than when spaced at 90 x 20 cm. Intercropping of castor and cluster bean proved to be advantageous. When castor and cluster bean were sown early in 2:2 row ratio, castor bean yield decreased by 32-36% in comparison with the sole crop. Yield reduction in intercropped cluster bean was 36-46% when sown early. Early sowing of the 2 intercrops increased mean LER over sole crops and gave the best monetary return/ha (Venkateswarlu and Reddy, 1989).

Giridhar and Giri (1991) obtained the highest seed yield (1018 kg/ha) for intercropped castor at the 90 cm row spacing with 1 row mung bean with mung bean yield of 200 kg/ha.

Kumar *et al*., (1993) reported that castor seed yields were decreased by about one third under paired row cropping. In the high rainfall year of 1990 pearl millet grain yield was higher when intercropped with castor than with cowpeas. Pearl millet stover yields were higher with cowpeas than with castor. Kumar *et al*., (1995) reported that castor seed yield was decreased by intercropping; in the triple row system the seed yield was 3 times less than in the paired row system. Gross monetary returns from sole castor were less than with the intercrops. The returns from the triple row intercrop was greater than from the paired row intercrop. The *P. glaucum*-grain-equivalent yield and gross return were highest with 40 kg N + 8.80 kg P. Sole castor, however, proved to be the best crop for the individual yield, whereas intercropping of pearl millet for fodder + castor was the best for pearl millet-grain-yield equivalent, followed

by pearl millet for grain + castor. Mono cropping of castor was not remunerative.

Tomar (1998) reported the highest castor-equivalent seed yield (1.42 t/ha), net return (Rs 8882/ha) and cost:benefit ratio (3:54) were obtained by sole cropping of soybeans. This was followed by castor + soybeans (1:2), castor + soybeans (1:1) and castor + urd (*Vigna mungo*) (1:2). The LER was higher under castor + urd (1:2). Kumar *et al.*, (1993) at New Delhi, found that castor seed yields were decreased by about 30% under paired rows while the cowpea intercrops failed in both years.

Under uniform planting of castor + clusterbean in 1:1 ratio and application of 10kg N and 30kg P_2O_5/ha to cluster bean component significantly increased the yield advantage (LER = 1.45) and additional gross returns with cluster bean harvested for vegetable purpose over the sole castor (Reddy and Venkateswarlu, 1989). In *Sourashtra* region of Gujarat and Anantapur district of Andhra Pradesh, groundnut + castor intercropping in the ratio of 3:1 was found to be very efficient. Higher yields and returns from castor based intercropping systems were recorded under modified plant geometries of castor at 90 cm, paired 60/120 cm and 60 cm to accommodate 2, 3 and 6 rows of intercrops -greengram, guar (clusterbean) and sesame under both irrigated and rainfed conditions at Mandore.

Varietal Response

Shankaralingappa and Hegde (1991) studied the varietal response in intercropping systems in castor in Karnataka and reported that seed yield in pure stands and when intercropped with *Macrotyloma uniflorum* was higher in cv. GAUCH-1 than in Aruna, while in the other intercrops yield was higher in Aruna. Mean yield of castor was decreased by intercrops in the order *Elusine coracana, M. uniflorum, Dolicos lablab*, and the effects varied with cultivar and year. Yields of *E. coracana, M. uniflorum* and *D. lablab* were decreased by intercropping compared with pure stands. LERs were higher in intercrops with *M. uniflorum* and *D. lablab* than with *E. coracana*, but net economic return was highest from the castor/ *E. coracana* intercrop.

Patel *et al.*, (1989) evaluated castor varieties in intercropping system. Rainfed castor cv. Aruna, GAUCH-I and GAUC-I intercropped with 3 crops gave av. seed yields of 0.30-0.41, 0.40-0.60 and 0.26-0.43 t/ha, respectively, compared with 0.79, 0.80 and 0.69 t, respectively, in pure stands. Gautam (1994) found that castor seed yields in intercropping were higher with MH-338 than MH-179.

Soil Moisture Conservation

Prasad *et al.*, (1993) assessed the soil and moisture conservation requirement of pure and intercropping in Vertisols at Kota and reported that castor yield was highest (1.09 t/ha) when grown in a pure stand using contour cultivation. Erosion was less with contour cultivation than up-and-down cultivation, and less in intercrops than in pure stands of castor. Water use efficiency among the cropping systems was highest in the intercrop using contour cultivation. Intercropping systems decreased leaching of N, P and K and increased soil fertility compared with pure stands of castor.

Selvaraj *et al.* (1992) reported that net income was highest when castor was intercropped with soybeans at an irrigation level of IW/CPE ratio of 0.6.

Sowing time, Variety/Crop Relay Crop

Reddy and Willey (1985) reported that growing a short-season mung bean before a castor crop reduced profits and yields of castor by delayed sowing. Relay-sowing the castor 20 days before the harvest of mung bean gave a greater profit than sole castor. Chandrasagar *et al.*, (1985) reported that under aberrant weather conditions for late sowing, intercropping of castor at 90 x 90 cm with two rows of coriander was found most economical for sowing in the week of 16 to 22nd July. Staggering planting time of either castor or clusterbean did not improve the total productivity of the intercropping system compared to sole cropping (Venkateswarlu and Reddy, 1989). The castor + cluster bean intercropping sown early with the onset of monsoon gave maximum yield with a LER of 1.38 than late sowings (Venkateswarlu, 1987).

As a contingency under severe drought spells affecting castor crop, the farmers of *Telangana* region of Andhra Pradesh, broadcast horsegram late in the month of August whenever the plant stand of castor is sparse (Hanumantha Rao and Chakrabarty, 1997).

Nutrient Management

At Hyderabad (Anon., 1989), recommended dose of fertilizers (RDF) of main crop to the system or RDF to main crop + RDF to intercrop on area basis did not vary significantly in influencing the yields of castor and intercrops (cluster bean, groundnut, sunflower and pigeonpea). The equivalent yield of castor in castor + groundnut (1:5) at recommended fertilizer dose of both crops on area basis was highest (1227kg/ha). Venkateswarlu *et al.* (1986) reported that in castor/sorghum rotation, castor productivity was optimum with the residual fertility in sandy red loam soil at Hyderabad.

Nitrogen application increased the castor bean yield with an optimum economic dose of 50.3 kg N/ha resulting in 394 kg castor bean/ha (Giridhar and Giri, 1991). Kumar *et al.* (1993) found that gross and net returns of the castor based intercropping system were highest with N + P + *A. brasilense* at New Delhi. Conjunctive use of green leaf manure and 40kg N/ha recorded similar yield of castor as that of 80kg N/ha (Vani and Bheemaiah, 2004).

Integrating 40kg N along with green leaf manuring gave

equivalent yields as that of 80 kg N/ha under alley cropping of castor with *Leuacena leucocephala* (Bheemaiah *et al.*, 1998).

Growth Analysis

At Coimbatore, Potiraj and Srinivasan (1992) in intercropping system with cotton found that at 45-60 d net assimilation ratio (NAR) was lowest in the cotton + castor + black gram system, but at 90-120 d it was unaffected by cropping system. RGR decreased with crop duration and was unaffected by fertilizer application. At 45-60 d relative growth rate (RGR) was highest in the cotton sole crop and lowest in the cotton + castor + black gram system. The cotton equivalent yield was highest with cotton + red gram (1.50 t/ha) and lowest with cotton + castor (1.1t).

Subramanian and Venkateswarlu (1989) analyzed the growth of intercrops of varying duration and found that intercropping decreased DM production, LAI, CGR and leaf growth rate of all the crops, but delayed leaf senescence in sorghum and pigeonpeas during seed/pod filling. Growth rates of reproductive organs and NAR were lower in the intercrops than in pure stands of the early component crops (sorghum, black gram and *C. tetragonoloba*) throughout the seed/pod filling phase, but only the growth rates of earlier formed pods/spikes were affected in the late component crops (pigeonpea and castor).

Jadhav *et al.* (1992) found that seed yield of pure castor (mean 0.62 t/ha) was greater than under intercropping (0.34-0.51 t). With the exception of castor + horsegram, intercropping produced greater net returns than the pure stand, albeit, not significantly. Castor intercropped with cluster beans (for seed) had the highest relative crowding coefficient in 3 out of 4 years in Maharashtra. Yadava (1992) from Rajasthan reported that seed yield of castor was 221 kg/ha when grown alone, 180-262 kg when intercropped with green gram and 132-248 kg when intercropped with *C. tetragonoloba*. Seed yields of green gram and *C. tetragonoloba* were 128 and 324 kg, respectively, when grown alone and 33-145 and 134-249 kg, respectively, when intercropped with castor. The highest land equivalent ratio of 2.0 was obtained when castor was intercropped with green gram in a 1:2 row ratio. Venkateswarlu and Subramanian (1990) reported that cluster bean was the most sensitive crop. Its yield was decreased by about 50% in stands intercropped with castor. In all crops, the reduction in yield of the intercrop due to a decrease only in the number of pods or seeds/unit area indicated that the adverse effects of intercropping began before the flowering stage. Land-equivalent ratio of pigeonpeas/ *Vigna mungo* stands was 1.50 compared with 1.22 for pigeonpeas/sorghum and castor/*C. tetragonoloba* stands; sorghum/pigeonpea intercropping was more productive than other 2 intercropping systems on the basis of dry matter production, economic yield and water use efficiency.

Pest Incidence in Intercropping Systems

Yadav *et al.* (1992) evaluated intercropping for the control of *Spilosoma obliqua* in Bihar. The greatest pest populations of *Spilosoma obliqua* in Bihar were recorded on the pure crops, while intercropping these crops with pigeonpea resulted in the lowest pest populations. The rate of natural parasitism by *Trichogramma chilonis* and a species of the genus *Meteorus* near *M. arctiicida* was relatively high in pure crops of castor, followed by black gram. Intercropping with pigeonpea adversely affected parasitism. Activities of larval parasitoids, including a species of the genus *Apanteles* near *A. obliquae, Carcelia sp.* and *Blepharella lateralis* were unaffected by intercropping. Crop-crop diversity studies as a key component of IPM in pigeonpea and castor based intercropping systems showed castor + clusterbean and pigeonpea + sorghum to harbour lower population of insect pests than sole and other intercrops (Anon., 2003).

At Palem (Anon., 1994) castor + pigeonpea system recorded lowest number of semi loopers and wilt incidence while castor + sesame enhanced the incidence of semi loopers and wilt compared to castor as sole crop. At SK Nagar, Gujarat, incidence of white fly, jassids and thrips were found to be significantly lower in all the intercropping systems where different base crops viz., clusterbean, cowpea, mungbean and groundnut were tried in 1:1 and 2:1 row ratios with castor compared to sole castor.

Mulik *et al.* (1996) in an experiment conducted during 1988-93 on Vertisols to study sustainability of rainy-season (*kharif*) cropping systems under rainfed conditions reported that Pearl millet, pigeonpea, sunflower, castor, groundnuts, sorghum, pearl millet + pigeonpea and green gram (*Vigna radiata*) were grown after each of these crops in the previous year, giving a total of 64 combinations. Yield of *P. glaucum* was almost the same when intercropped as when grown alone, giving higher net returns and sustainable value index from the intercropping system. *P. glaucum* was the most profitable and sustainable of the sole crops, and gave its highest yield (2.11 t/ha) after sunflowers. Sorghum and groundnuts were the next most profitable crops, while green gram gave the lowest net returns and sustainable value index.

Raising a crop of castor around chillies and tomatoes in citrus orchards was found to control fruit borer and sucking moths. Castor around the cotton field attracts boll worms and sucking pests and protects the main crop. In Andra Pradesh, castor is grown as a trap crop around tobacco field to control *Spodoptera litura*, army worm affecting the crop.

Castor in Agroforestry

In a dry land alley cropping experiment during beginning two years of *Acacia albida* planted at 3 alley widths (of which the smallest was 3.0 m), castor, sunflower and

redgram crop growth and yield were increased in both years of the study, and at all 3 alley widths, in comparison with sole crops. Height and girth growth of the trees were not reduced by the intercrops but were better in association with castor and redgram than with sunflower, and at the smallest alley width. Whereas, under *Dalbergia sisoo*, during the 2 years, yields of sunflower, castor and red gram did not vary much, except that during the second year the yields of red gram were reduced considerably. However, the mean yields of sunflower and castor when intercropped were similar and higher (Vani and Bheeemaiah, 2004) to those of the respective sole crops. The gross returns were also higher in sunflower and castor crops under intercropping and sole cropping than those of red gram. Generally, the crops did not inhibit tree growth, but the rate of increment was slightly reduced in association with red gram (Subrahmanyam *et al.*, 1996). Ismail *et al.*, (1993) under 3-year-old budded ber (*Ziziphus mauritiana*) eported that intercropping with annual crops did not affect either crops. The fruit yield of ber was not affected by intercropping with sunflower or castor, but intercropping with pigeon pea caused a marked yield reduction. The mean overall gross monetary return was highest with ber + sunflower, followed by ber + castor, when compared with either sole ber or sole annual crops.

Yield of castor was significantly higher under alley cropping with *Leuacena leucocephala* over sole cropping (Bheemaiah et al., 1998), Whereas, intercropping castor with *Melia azedarach* was not compatible (Sarada Devi *et al.*, 2002). Rao *et al.* (1991) evaluated the intercropping system under agro-forestry system with *Leucena* at Hyderabad. Except in the first year, crop yields were suppressed by *Leucaena* due to competition for moisture. The severity of competition was high in years of low rainfall and on long-duration crops such as castor and pigeon pea. Based on total biomass, sole *Leucaena* was most productive. Even on the basis of land productivity requiring both *Leucaena* fodder and annual crops, alley cropping had little or no advantage over block planting of both components. Application of hedge prunings as green manure or mulch on top of 60 kg N and 30 kg P_2O_5/ha to annual crops did not show any benefit during the experimental period, characterized by below average rainfall.

Studying the allelopathic effect of *Eucalyptus grandiflora* trees on castor, Sahadeva Reddy *et al.*, (2004) reported that up to 4-5m, castor plants could not grow and seed yield of castor increased with increasing distance, beyond 5-6m from the *Eucalyptus* trees.

Stability of Castor Involving Intercropping Systems

Kumar and Gautam (1992) compared cultivars, spacing, intercropping treatments and fertilizer treatments for pearl millet at New Delhi during the *kharif* seasons of the drought year of 1989 (193 mm rain during *kharif*) and the normal rainfall year of 1990 (690 mm during *kharif*). Biomass yield was higher in the hybrid cv. MBH-151 in 1989, whereas the composite ICMS-7703 produced the higher yield in 1990. Yield in 1989 was higher with uniform 60 cm rows than in 30/70 cm paired rows. In 1990, biomass production was higher in pearl millet intercropped with cowpeas than with castor. Among fertilizer treatments, yield was in the order 25 kg N + 12.5 kg P_2O_5/ha + *Azospirillum* 25 kg N + 12.5 kg P_2O_5 5 t FYM/ha control (no fertilizers). Residual N in the soil after harvest was not affected by fertilizer treatment but was higher after intercropping with cowpeas than with castor.

Intercropping castor did not affect seed yield. When seasonal rainfall was satisfactory (426-606 mm, 1984-86) highest total yield (3.91 t/ha) and highest net returns were obtained with castor at plant spacings of 100 X 30 cm 2 rows of *V. radiata* between 2 rows of castor. During drought conditions (1986-87) the intercrop failed and castor gave the highest seed yield of 1.63 t when sown at 100 X 50 cm spacing (Rao *et al.*, 1989). Chouhan *et al.*, (1994) found that castor intercropping with sesame and green gram gave highest yields of castor, and highest net returns under both irrigated and rainfed conditions with all 3 spacing systems.

Castor was found to impart yield stability under varied weather conditions. In Rajkot region (Anon, 1989) when castor was component crop with either groundnut or pearl millet, its yields were maintained at about 9 q/ha at situations of both high rainfall as well as low rainfall years, while the base crop yields were adversely affected under situations of low rainfall. Similar results were found at Hyderabad region where castor was a base crop for pigeon pea, setaria, cowpea, greengram and sorghum as intercrops.

Impact of Adaptation

In field appraisals of castor based intercropping systems through frontline demonstrations both under irrigated and rainfed conditions at Mandore and Junagadh, all the castor based intercropping systems with guar, greengram, sesame and groundnut gave higher seed yield and net returns compared to the farmer's practice of growing castor as a sole crop (Anon., 1993; 1994). For an additional expenditure incurred in castor based intercropping systems to the tune of Rs.115 to 850/ha, the additional returns realized was to the tune of Rs.1750 to 13344/ha.

Reddy *et al.*, (1989) in an evaluation study of the impact and adoption of improved dryland crop production techniques in the watershed area of the Operational Research Project of the Hyderabad region of Andhra Pradesh from 1976 to 1983 found that intercropping systems including sorghum or pearl millet with pigeon peas and castor increased the productivity and income over their sole cropping.

Summary

The literature search on intercropping indicate that castor was compatible with many crops for intercropping at many centers except with sesame at Palem. The normal row ratios tried varied from 1:1 to 1:5 with different crops. Limited reports on nutrient management in intercropping system indicate that fertilizing both the crops at their RDF has given higher yields and efficiency of intercropping. Castor + pigeonpea intercropping was found to reduce incidence of wilt and semi looper at Palem. Castor based intercropping was proved to be productive and profitable when evaluated in farmers fields through frontline demonstrations.

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Genetic divergence in soybean, *Glycine max* (L.) Merrill*

M.V. Ramana and A. Satyanarayana**

Regional Agricultural Research Station, Lam, Guntur-522 034, AP

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Abstract

Seventy soybean genotypes representing diverse geographic regions were studied for genetic divergence using Mahalanobis' D^2 statistic. The genotypes were grouped into nine clusters. No linear relationship between geographic and genetic divergence was observed. Plant height, plant dry weight, 1000 seed weight contributed maximum to the total genetic divergence. The maximum inter cluster distance was observed between cluster IV and VII. Selection of the genotypes from these clusters for hybridization programme may result into good recombinants.

Key words: *Soybean, genetic divergence*

Introduction

Genetic diversity is the basis requirement for successful breeding programme in any crop. Success of crop improvement programme depends on the extent of genetic variability, choice of parents for hybridization and selection procedure adopted. The choice of genetically diversed parents is important in hybridization programme to create variation for selection of useful recombinants. D^2 statistic developed by Mahalanobis (1936) is a powerful tool to measure genetic divergence among genotypes in any crop. It appears that relatively very little work has been reported so far in Andhra Pradesh which is emerging potential non-traditional soybean growing state in India. Hence, an attempt has been made to study the genetic divergence in seventy soybean genotypes developed at various research centres of the country.

Materials and methods

Seventy soybean genotypes obtained from 17 research stations of India were studied in a Randomized Block Design with two replications at the Regional Agricultural Research Station, Lam during *kharif*, 2000-01. The soil of the experimental site is deep black cotton soil and the crop was raised under rainfed situation. Each genotype was raised in two rows of five meter length spaced at 30 cm between rows and 7.5 cm within the row. Five plants were selected randomly from each plot and observations for fourteen characters were recorded for days to 50% flowering, days to maturity, plant height (cm), number of branches/plant, number of pods/plant, pod length (cm), seeds/pod, 100 seed weight (g), plant dry weight (g), harvest index (%), seed protein (%), oil content (%), shoot nitrogen at anthesis (%) and grain yield/plant (g). Protein content was estimated based on total nitrogen content of seeds by micro-kjeldahl method by multiplying percentage N by 5.71 (Sadasivam and Manickam, 1992) oil content was estimated by the nuclear magnetic resonance (NMR) technique. The analysis of genetic divergence was carried out using Mahalanobis's D^2 statistics. The seventy genotypes studied were grouped in clusters by the Tocher's method as described by Rao (1952).

Results and discussion

Analysis of variance showed significant differences among the genotypes for all the 14 characters studied. The D2 values of the possible 2415 combinations ranged from 30.32 (between JS (SH) 94.23 and VLS 54) to 1911.68 (between LSb 1 and MAUS 61-2). The seventy genotypes were grouped into nine clusters.

The results of the present study revealed that distribution of genotypes into different clusters was at random and no relationship was observed between geographic origin and genetic diversity as the genotypes developed from different geographic regions were included in the same clusters (Table 1). This was in agreement with the findings of Mehetre *et al.* (1997) and Ganesamurthy and Seshadri (2002). The per cent contribution towards genetic divergence by all the 14 contributing characters is presented in Table 2. The maximum contribution towards genetic divergence is by plant height (22.28 %) followed by plant dry weight (15.49%) and 100 seed weight (13.25 %). Chikale *et al.* (1992) reported maximum contribution of 100 seed weight and plant height towards total genetic divergence. Ganesamurthy and Seshadri (2002) observed maximum contribution of 100 seed weight and pods per plant towards genetic divergence while yield/plant and number of pods/plant by Dobhal (1995).

The average intra and inter-cluster distances are presented in Table 3. The intra-cluster distance ranged from 229.9

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** Director of Extension, ANGRAU, Rajendranagar, Hyderabad-500 030, AP.

(cluster VIII) to 304.7 (cluster III). The maximum inter cluster distance was observed between cluster IV and VII followed by cluster II and VII. The least inter cluster distance was observed between cluster V and cluster IX. Hybridization between genotypes from distant clusters resulted in desirable recombinants in the progenies. The cluster mean values for 14 characters were studied in Table 4. They clearly indicate differences of genotypes in the clusters. The cluster IV recorded the highest mean for grain yield/plant, number of pods/plant, plant dry weight and shoot nitrogen content at anthesis while cluster VIII recorded the highest protein content and cluster IX recorded the highest oil content.

Table 1 Clustering pattern of 70 soybean genotypes during *kharif*, 2000

Cluster No.	No. of genotypes	Genotypes
I	8	HIS 01, JS (SH) 95-26, KB 221, LSb 9, MACS 694, TS 99-76, TS 2000-20, MAUS 64-1
II	7	AMS 97-1, DSb 5, JS 93-07, JS 94-66, JS (SH) 93-37, MAUS 61-2, TS 98-21
III	6	HIMSO 1587, HIMSO 1588, JS 93-05, JS 94-65, LSb 1, LSb 4
IV	7	AMS 97-2, DSb 1, JS 335, JS 94-67, MAUS 61-1, MAUS 71, MACS 450
V	10	Bragg, JS (SH) 94-167, LSb 5, LSb 6, Lsb 8, MACS 201, MACS 681, NRC 52, PK 1274, PK 1283
VI	7	KB 222, LSb 3, MACS 730, MAUS 2, MAUS 62-2, MAUS 81, MACS 693
VII	3	DS 97-12, JS 90-41, VLS 53
VIII	9	DSb 2, MACS 666, MACS 740, NRC 51, NRC 53, PK 472, PK 1029, RAUS 5, TS 2000-129
IX	13	DS 97-11, JS 93-06, JS (SH) 93-01, JS (SH) 94-23, LSb 7, MAUS 59, PK 1284, SL 328, SL 428, SL 528, SL 603, TS 99-128, VLS 54

Table 2 Contribution of different characters towards genetic divergence in 70 soybean genotypes during *kharif*, 2000

Character	% contribution towards divergence	Rank
Days to 50% flowering	3.15	9
Days to maturity	7.37	6
Plant height (cm)	22.28	1
Number of branches/plant	9.86	4
Number of pods/plant	9.40	5
Pod length (cm)	0.25	14
Seeds/pod	2.32	11
100-seed weight (g)	13.25	3
Plant dry weight (g)	15.49	2
Harvest index (%)	2.28	12
Seed protein content (%)	4.47	8
Oil content (%)	1.12	13
Shoot nitrogen (%)	6.25	7
Grain yield per plant (g)	2.53	10

Table 3 Average intra and inter-cluster D^2 values among 9 clusters for 70 genotypes of soybean during *kharif*, 2000

Cluster No.	I	II	III	IV	V	VI	VII	VIII	IX
I	**252.2**	390.3	502.3	583.4	403.1	400.9	452.6	496.3	333.9
II		**250.1**	481.4	328.7	394.3	328.5	655.7	361.5	359.6
III			**304.7**	522.0	382.2	580.6	487.1	478.1	411.7
IV				**248.7**	365.3	330.6	689.6	336.9	474.3
V					**232.3**	294.5	375.7	278.9	243.8
VI						**230.8**	531.5	291.7	353.3
VII							**233.5**	556.9	368.6
VIII								**229.9**	400.5
IX									**234.8**

Table 4 Mean values of clusters for 70 genotypes of soybean during *kharif*, 2000

Cluster No.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	Pod length (cm)	Seeds/ pod	100 seed weight (g)	Plant dry weight (g)	Harvest index (%)	Seed protein content (%)	Oil content (%)	Shoot nitrogen (%)	Grain yield/ plant (g)
I	40.75	102.38	60.61	2.85	37.04	3.86	2.17	12.02	26.46	33.02	38.15	20.50	2.73	8.64
II	43.43	102.00	51.74	3.56	58.03	4.16	2.44	10.97	32.95	37.98	38.72	20.89	3.03	12.53
III	35.50	90.50	40.57	2.78	41.10	4.18	2.68	12.30	22.42	45.75	38.00	20.49	3.08	10.46
IV	40.00	101.00	50.88	3.50	59.19	4.05	2.38	13.03	34.56	44.75	37.74	21.34	3.88	15.45
V	36.40	98.90	46.60	3.20	45.66	3.77	2.12	13.31	26.80	44.68	37.61	21.59	3.10	11.94
VI	43.43	103.57	51.04	3.61	50.51	3.60	2.06	14.16	34.21	39.52	37.67	21.23	3.16	13.46
VII	38.33	96.67	37.48	2.30	30.40	3.47	2.03	14.64	17.33	40.75	37.03	21.44	2.98	7.12
VIII	38.00	100.11	41.19	3.96	51.13	3.84	2.14	14.45	31.78	43.36	40.26	21.07	3.22	13.72
IX	40.62	102.77	41.60	3.45	42.19	3.89	2.25	11.61	23.97	40.30	37.20	21.75	2.86	9.59

The results indicate that the inclusion of genotypes grouped in cluster IV (AMS 97-2, DSb 1, JS 335, JS 94-67, MAUS 61-1, MAUS 71, MACS 450), VII (DS 97-12, JS 90-41, VLS 53) and II (Himso 1587, Himso 1588, JS 93-05, JS 94-65, LSb 4) with high inter cluster distances in the hybridization programme in soybean is expected to give useful segregants in subsequent generations.

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Combining ability analysis in soybean, *Glycine max* (L.) Merrill*

M.V. Ramana and A. Satyanarayana[1]

Regional Agricultural Research Station, Acharya N.G. Ranga Agril. University, Lam, Guntur-522 034, AP

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Abstract

Combining ability analysis was studied in line x tester model for 14 yield and yield component characters. *Results revealed that predominance of additive gene* action for days to 50% flowering, days to maturity, plant height (cm), number of branches/plant, number of pods/plant, *pod length (cm), seeds/pod, 100-seed weight (g), plant dry weight (g),* harvest index (%), protein content (%), oil content (%), shoot nitrogen at *anthesis (%) and grain yield/plant (g), DSb 1, LSb 3 and* PK 472 were found to be good general combiners for grain yield/plant. *LSb 1, JS 90-41, JS 335 and MACS* 201 were found good general combiners for days to maturity. The cross DSb 1 x PK 1029 was the best specific combination for grain yield.

Key words: Soybean, combining ability

Introduction

Selection of the parents in the hybridization programme is very important for getting desirable recombinants in crop like soybean where hybridization followed by pedigree method is most commonly used. The information on gene actions associated with yield and yield component traits in soybean is scanty in non-traditional soybean growing area, Andhra Pradesh. Hence, the present investigation was undertaken to assess the nature of gene action involved in the inheritance of yield and its components along with quality traits and also to identify the best general combiners for different traits and the best cross combinations having high *sca* effects which can be exploited for the improvement of various characters in soybean through line x tester analysis.

Material and methods

Eight soybean genotypes were crossed in line x tester model using four females (LSb 1, LSb 3, DSb 1 and JS 90-41) and four males (PK 472, JS 335, PK 1029 and MACS 201). The resulting 16 F_1s and eight parents were studied in a randomized block design with three replications during *kharif*, 2001 at Regional Agricultural Research Station, Lam during *kharif*, 2001. Each plot consisted of two rows of five meter length with a spacing of 30 cm between the rows and 7.5 cm within the row. Data was recorded on ten randomly selected plants for 14 characters *viz.*, days to 50% flowering, days to maturity, plant height (cm), number of branches/plant, number of pods/plant, pod length (cm), seeds/pod, 100-seed weight (g), plant dry weight (g), harvest index (%), seed protein content (%), oil content (%), shoot nitrogen at anthesis (%) and grain yield/plant (g). Protein content was estimated based on total nitrogen content of seeds by micro-kjeldahl method by multiplying percentage N by 5.71 (Sadasivam and Manickam, 1992), oil content was estimated by the nuclear magnetic resonance (NMR) technique. The estimates of combining ability analysis were calculated as per the method suggested by Kempthorne (1957).

Results and discussion

The results of analysis of variance for different characters are presented in Table 1. It revealed that parents and crosses were significant for all the characters except for number of primary branches/plant, pod length and protein content among the parents and seeds/pod and shoot nitrogen content at anthesis among the hybrids, indicating the presence of variability. Higher and significant mean squares for lines than testers indicated greater contribution of lines to higher *'sca'* effects than that by the testers. The interaction between lines and testers were significant for days to 50% flowering, days to maturity, plant height (cm), number of pods/plant, 100-seed weight (g), harvest index (%) and grain yield/plant (g) suggest that there is considerable variation among the crosses.

The estimates of variances for general combining ability and specific combining ability have been presented in Table 1. The ratio of general combining ability component of variance to the total genetic variance was found to be high for all the characters studied except for seeds/pod indicating the preponderance of additive gene action governing the characters. As additive gene action was found to be predominant, desirable segregants can be isolated in subsequent generations through simple selection methods like pedigree method. Additive gene action for various important economic traits was also reported by Halvankar and Patil (1993), Sood *et al.* (2000),

* Part of the Ph.D. Thesis submitted to Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, AP.

[1] Director of Extension, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, AP.

Ganesamurthy and Seshadri (2002), Rahangdale and Raut (2002). The *sca* variance was higher for number of seeds/pod indicating predominance of non-additive gene action for this trait. Raut *et al.* (2000) also reported the importance of non-additive gene action for seeds/pod.

The *gca* effects (Table 2) revealed that among the lines, DSb 1 was a good general combiner for plant height, branches/plant, pods/plant, pod length, 100-seed weight, plant dry weight, harvest index, oil content, shoot nitrogen at anthesis and grain yield/plant, LSb 3 for pods/plant, plant dry weight, seed protein content, oil content, shoot nitrogen at anthesis and grain yield/plant. Among the testers, PK 472 was a good combiner for pods/plant, pod length, plant dry weight, harvest index and grain yield/plant and JS 335 for days to maturity, seed protein and oil content. The lines LSb 1 and JS 90-41 and testers, JS 335 and MACS 201 showed negative *gca* effects for days to maturity and they may be used in breeding programme aimed at short duration types.

The specific combining ability effects for all crosses are presented in Table 3. The best specific cross for grain yield/plant was DSb 1 x PK 1029. The same cross showed high *sca* effects for number of pods/plant, 100-seed weight, plant dry weight and pod length. This cross involved high x low general combiners and hence may be advanced through recurrent selection procedures to exploit both additive and non-additive gene actions. The cross, LSb 1 x PK 1029, DSb 1 x PK 472 and JS 90-41 x MACS 201 recorded significant negative *'sca'* effects in the desired direction for days to maturity.

Table 1 ANOVA for combining ability (mean squares) for grain yield and its components in F_1 generation

Source of variation	Degrees of freedom	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches/plant	No. of pods/ plant	Pod length (cm)	Seeds/ pod	100 seed weight (g)	Plant dry weight (g)	Harvest index (%)	Seed protein content (%)	Oil content (%)	Shoot nitrogen (%)	Grain yield/ plant (g)
Parents	7	26.643**	377.809**	78.807**	0.757	458.735**	0.139	0.274	15.381**	140.060**	51.560**	2.248	1.583**	0.145*	22.288**
Hybrids	15	20.750**	249.932**	47.878**	1.904**	936.689**	0.262*	0.101	9.413**	217.903**	29.796**	4.493*	1.951**	0.062	38.465**
Lines	3	83.417**	1150.552**	137.615**	4.954*	1808.863**	0.437	0.085	34.389**	931.901**	51.903*	12.809*	0.753	0.158	159.644**
Testers	3	4.084	40.996	19.229	1.899	147.866	0.468	0.092	4.971	74.432	58.842**	3.755	0.675	0.026	14.561
Line x Testers	9	5.417**	19.371**	27.516**	0.889	44.306**	0.135	0.109	2.567**	27.724*	12.744**	1.968	0.516	0.043	6.041*
Error	30	1.400	2.749	5.458	0.555	4.280	0.095	0.061	0.685	10.929	0.679	2.382	0.397	0.051	3.247
$\sigma^2 gca$		6.390	96.070	8.480	0.420	155.680	0.050	-0.010	2.850	79.240	7.100	1.050	0.600	0.010	13.510
$\sigma^2 sca$		1.340	5.540	7.350	0.110	0.500	0.010	0.060	0.630	5.600	1.980	0.140	0.040	0.001	0.930
$\frac{2\sigma^2 gca}{2\sigma^2 gca + \sigma^2 sca}$		0.910	0.980	0.700	0.880	0.990	0.910	-0.500	0.900	0.970	0.880	0.940	0.970	0.950	0.970

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

Table 2 Estimates of general combining ability (*gca*) effects of parents in F_1 generation

Source of variation	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	Pod length (cm)	Seeds/ pod	100 seed weight (g)	Plant dry weight (g)	Harvest index (%)	Seed protein content (%)	Oil content (%)	Shoot nitrogen (%)	Grain yield/ plant (g)
Lines														
LSb 3	1.88**	8.92**	-0.19	-0.49**	5.80**	-0.01	0.02	0.11	4.43**	-0.47	0.73*	0.42**	0.10*	1.55**
LSb 1	-3.79**	-13.42**	-3.85**	-0.06	-15.18**	0.08	0.01	1.22**	-10.91**	1.71**	-1.20**	-1.19**	-0.13*	-3.93**
DSb 1	1.71	5.25**	4.40**	0.93**	13.18**	0.19**	-0.12*	1.09**	9.29**	1.51**	-0.51	0.45**	0.10*	4.29**
JS 90-41	0.21	-0.75*	-0.36	-0.38*	-3.80**	-0.26**	0.08	-2.43**	-2.81**	-2.75**	0.98**	0.32*	-0.06	-1.91**
SEm±	0.24	0.34	0.48	0.15	1.34	0.06	0.05	0.17	0.67	0.53	0.32	0.13	0.05	0.37
Testers														
PK 472	0.71**	1.58**	0.02	-0.34*	4.78**	0.16**	-0.05	0.20	2.80**	2.08**	-0.22	-0.30*	-0.01	1.65**
PK 1029	-0.62*	1.58**	-1.64**	0.08	-2.87*	-0.11	0.12*	0.64**	-3.09**	1.66**	-0.46	0.05	-0.03	-0.53
JS 335	0.21	-1.25**	0.16	-0.27	0.46	-0.22**	-0.08	-0.89**	0.92	-2.41**	0.81*	0.27*	0.07	-0.44
MACS 201	-0.29	-1.92**	1.45**	0.53**	-2.37	0.17**	0.02	0.05	-0.64	-1.34**	-0.13	-0.02	-0.03	-0.67
SEm±	0.24	0.34	0.48	0.15	1.34	0.06	0.05	0.17	0.67	0.53	0.32	0.13	0.05	0.37

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

Table 3 Estimates of specific combining ability (*sca*) effects of crosses in F_1 generation

Cross	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	Pod length (cm)	Seeds/ pod	100 seed weight (g)	Plant dry weight (g)	Harvest index (%)	Seed protein content (%)	Oil content (%)	Shoot nitrogen (%)	Grain yield/plant (g)
LSB 3 x PK 472	-0.38	-0.75	0.82	0.15	5.06*	0.08	0.20*	-0.79**	-1.00	0.93	-0.86	0.47*	0.05	0.24
LSB 3 x PK 1029	-0.38	-0.75	3.51**	-0.34	-4.87*	-0.08	0.03	0.75*	0.40	1.89*	1.50*	0.28	0.10	0.72
LSB 3 x JS 335	0.12	2.75**	-3.48**	-0.11	2.78	-0.02	-0.16	-0.60*	2.48*	-1.49	-0.18	-0.71**	0.09	0.23
LSB 3 x MACS 201	0.62	-1.25*	-0.85	0.30	-2.98	0.02	-0.06	0.65*	-1.88	-1.33	-0.46	-0.04	-0.24**	-1.19
LSB 1 x PK 472	1.29**	-1.75**	-0.86	-0.54*	-0.23	-0.03	-0.13	-1.09**	-1.77	2.54**	0.68	-0.31	0.01	-0.18
LSB 1 x PK 1029	-1.38**	-2.42**	0.74	-0.27	-2.94	-0.05	-0.10	-1.11**	-0.55	-1.45	-0.55	-0.33	-0.10	-0.90
LSB 1 x JS 335	-0.21	1.75**	-0.23	0.71**	0.90	0.16	-0.11	0.69*	0.04	-1.49	-0.08	0.68**	-0.02	-0.04
LSB 1 x MACS 201	0.29	2.42**	0.34	0.10	2.27	-0.07	0.13	-0.67*	2.29	0.40	-0.04	-0.04	0.11	1.12
DSB 1 x PK 472	-2.21**	0.25	-1.47	-0.36	-2.72	0.15	-0.13	0.17	-1.30	-1.92*	0.33	-0.21	-0.07	-1.02
DSB 1 x PK 1029	1.12*	2.92**	-1.23	0.23	4.33*	0.22*	0.03	0.65*	3.95**	1.39	-1.16*	-0.01	-0.02	2.16**
DSB 1 x JS 335	0.29	-3.58**	5.01**	0.03	-2.69	-0.06	0.30**	-0.94**	-3.49**	0.39	0.30	0.08	0.00	-1.38**
DSB 1 x MACS 201	0.79	0.42	-2.31**	0.10	1.09	-0.31**	-0.20*	0.12	0.84	0.13	0.54	0.14	0.09	0.25
JS 90-41 x PK 472	1.29**	2.25**	1.51	0.75**	-2.10	-0.20	0.06	-0.47	4.07**	-1.55	-0.15	0.05	0.01	0.96
JS 90-41 x PK 1029	0.62	0.25	-3.03**	0.38	3.49	-0.09	-0.17	-0.29	-3.79**	-1.83	0.21	0.05	0.03	-1.98**
JS 90-41 x JS 335	-0.21	-0.92	-1.30	-0.64*	-1.00	-0.08	-0.03	0.85**	0.97	2.58**	-0.03	-0.04	-0.08	1.19
JS 90-41 x MACS 201	-1.71**	-1.58*	2.82**	-0.49	-0.38	0.37**	0.13	-0.09	-1.25	0.80	-0.03	-0.06	0.04	-0.18
SEm±	0.42	0.59	0.83	0.26	2.31	0.11	0.09	0.29	1.17	0.92	0.55	0.22	0.08	0.64

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

Hence, present combining ability analysis revealed predominance of additive gene action for all the traits studied except for seeds/pod where non-additive gene action was predominant. Among the lines, DSb 1 and LSB 3 and among the testers, PK 472 was found to be good general combiners for yield and most of the yield components. The cross, DSb 1 x PK 1029 showed good specific combining ability for grain yield/plant coupled with high *per se* performance and heterosis.

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Generation mean analysis of some important quantitative characters in gobhi sarson, *Brassica napus* L.

Mukesh Kumar, B.S. Chaudhary and J.B. Singh

Department of Agricultural Botany, J.V. College, Baraut, Baghpat-250 611, UP

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Abstract

Genetic analysis of 45 F_1s of *Brassica napus* L. developed through half diallel crossing of 10 diverse parents excluding reciprocals, revealed significant additive and dominance effects with three types of epistatic interactions in most of the crosses for all eight characters. Duplicate epistasis was predominant in majority of crosses for all the characters. Additive x additive (in all crosses) and dominance x dominance interaction (in seven) were significant for seed yield, hereby indicating the importance of both type of gene action. In general, dominant effect was higher than additive effect for seed yield and most of the yield attributing components. Oil content was found to be controlled by additive x additive interaction in two crosses and by dominance x dominance in one cross.

Key words: *Gene effects, interaction, yield traits, gobhi sarson*

Introduction

In Indian mustard, the genetic variability is limited for several characters including seed yield (Uddin *et al.*, 1983; Rai, 1989). There is stagnation in seed yield potential, mainly due to the narrow genetic base available with the researchers working on rapeseed and mustard. Thus, it is very essential to widen the genetic base of rapeseed and mustard varieties through wide hybridization. An alternative, however, would be to replace or diversify the crop by releasing the varieties of other species such as *gobhi sarson* (*Brassica napus*) and Ethiopian mustard (*Brassica carinata*), etc. Among these, *gobhi sarson* possess high yield potential with high oil content across the world. To develop an efficient genotype, the knowledge of gene action and relative magnitude of additive and non-additive genetic variance is a pre-requisite to design an efficient breeding scheme. The present study is an attempt in this direction with a view to study the genetics of yield components in *gobhi sarson*.

Materials and methods

The experimental material comprised of 45 F_1s, developed through half-diallel crossing of 10 diverse parents i.e., ISN-114, TR-3, GSL-1, ISN-706, *B. napus-1*, *B. napus*-2, *B. napus* (E)-1, *B. napus* (E)-2, EC-400802 and EC 400803 in all possible combinations excluding reciprocals. On the basis of performance of 45 F_1s, the top 10 F_1s were selected for genetic analysis. The F_1s of selected crosses were backcrossed with their respective parents to get BC_1 and BC_2 progenies and were simultaneously selfed to obtain F_2 seeds. The experimental material consisting of 50 lines (10 parents, 10 F_1s, 10 F_2s, 10 BC_1s and 10 BC_2s) representing 5 generations were grown at the experimental farm of J.V. College, Baraut, Baghpat (UP) in Randomized Block Design with three replications during *rabi*, 2001. Each genotype was sown in five rows of 3 m length. A spacing of 45 cm x 15 cm was maintained between rows and plants. The crop was raised following the normal recommended package of practices. Observations were recorded on number of primary and secondary branches, main shoot length, siliquae on main shoot, seeds/siliqua, 1000-seed weight, seed yield and oil content on 10 randomly selected plants from each parents and F_1s 15 plants from each backcross population and 30 plants from each F_2 populations. Mean values of each generations were used for studying gene effects for each traits..

Results and discussion

Gene effects

The estimates of component 'd' were significant for number of secondary branches in crosses ISN-706 x *B. napus* (E)-2 and *B. napus* (E)-1 x EC 400802, for length of main shoot in crosses *B. napus* (E)-1 x *B. napus-1* and *B. napus* (E)-2 x EC 400802, for 1000 seed weight, in crosses *B. napus* (E)-1 x *B. napus*-1 and ISN-144 x EC 400802, for seed yield/plant, in cross TR-3 x *B. napus*-1 and for oil content in cross ISN-706 x *B. napus-2*. Component 'h' was significant for primary branches in crosses *B. napus* (E)-1 x *B. napus-1*, TR-3 x ISN-706, TR-3 x *B. napus-1* and GLS-1 x *B. napus* (E)-1, for length of main shoot in crosses *B. napus* (E)-2 x EC 400802 and ISN-706 x *B. napus*-2 for number of siliquae on main shoot in crosses ISN-706 x *B. napus* (E)-2, *B. napus* (E)-1 x *B. napus*-1 and EC 400802 and ISN-706 x *B. napus*, for 1000 seed weight in crosses *EC-400802 x EC 400803* and ISN-706 x *B. napus-2*. Out of the ten crosses, seven showed significant 'h' component for seed yield while oil content was significant but in negative direction.

Among the epistatic components, the estimates of additive x additive component 'l' was significant for number of primary branches in crosses ISN 114 x EC 400803, TR 3 x *B. napus-1* and GSL 1 x *B. napus* (E)-1, for main shoot length in *B. napus* (E)-2 x EC 400802 and ISN 706 x *B. napus*-2, for number of siliquae on main shoot in ISN 706 x *B. napus*(E)-2, *B. napus*(E)-1 x *B. napus-1*, *B. napus-1* x EC 400802 and EC 400802 x EC-400803, for number of seeds/siliqua in ISN 114 x EC 400803, for 1000 seed weight in crosses EC 400802 x EC 400803, TR 3 x *B. napus-1* and ISN 706 x *B. napus-2* and for oil content in cross *B. napus* (E)-2 x EC 400802. Eight crosses showed significant additive x additive component or seed yield. Additive x dominance component ('j') was significant for number of secondary branches, length of main shoot and 1000 seed weight (g) in crosses ISN 706 x *B. napus* (E)-2, *B. napus* (E)-1 x *B. napus*-1, ISN 114 x EC 400803, respectively. Dominance x dominance ('l') was significant for siliquae on main shoot in crosses *B. napus* (E)-2 x EC 400802 and TR 3 x *B. napus*-1 and in ISN 114 x EC 400803 for oil content. Partitioning of the genetic components of variances indicated that dominance effects were higher than additive effects for primary branches. Pradhan *et al.* (1993) and Kumar *et al.* (1994) reported both additive and non-additive gene effects. Positive and significant additive gene effects were also reported by Singh and Yaspal (1991) for length of main shoot.

Table 1 Estimates of genetic effects for eight yield traits and oil content based on ten crosses in Gobhi *Sarson*

Cross	Gene effect							Type of Epistasis
	m	d	h	l	j	l	χ^2	
Number of primary branches								
ISN-114 x EC-400803	7.38**	0.33	3.17	4.20*	0.96	-9.76**	6.31**	*Duplicate*
TR-3 x ISN-706	6.10**	1.00	7.12*	4.52	-	-	5.08	-
TR-3 x *B. napus*-1	6.30**	2.20	7.93*	8.27*	2.03	-15.87*	12.49**	Duplicate
GLS-1 x *B. napus* (E)-1	5.43**	0.53	8.86*	9.43**	*0.43*	*-14.69*	*8.27***	*Duplicate*
B. napus (E)-1 x *B. napus*-1	6.08**	-1.05	6.57*	5.33	-0.95	-4.64	7.60*	Duplicate
Number of secondary branches								
ISN-114 x EC-400803	6.31**	0.53	7.38*	4.11	1.13	-3.32	3.70	Duplicate
TR-3 x ISN-706	5.76**	1.64	7.00**	2.57	1.10	4.16	26.24**	Complementary
TR-3 x *B. napus*-1	5.47**	3.02**	8.31**	8.62**	1.99	-18.22**	16.83**	Duplicate
GLS-1 x *B. napus* (E)-1	4.75**	-1.42	10.72**	10.27**	-0.77	-19.13**	24.71**	Duplicate
ISN-706 x *B. napus*-2	9.41**	-1.85*	5.92	-6.66*	-1.97	-1.98	54.60**	Duplicate
ISN-706 x *B. napus* (E)-2	5.31**	2.52**	17.77**	6.41*	2.27*	1.01	*16.61***	*Complementary*
B. napus (E)-1 x *B. napus*-1	5.42**	-0.57	13.00**	10.17**	-1.17	-16.67**	14.67**	Duplicate
B. napus (E)-2 x EC-400802	7.80**	-2.23	-3.06	-5.80	-1.48	8.25	10.20**	Duplicate
B. napus-1 x EC-400802	3.58**	4.78**	19.38**	17.46**	5.79**	-24.02**	79.44**	Duplicate
EC-400802 x EC-400803	4.60**	-3.26*	14.17**	11.07**	-3.19*	-8.64	27.52**	Duplicate
Length of main shoot (cm)								
TR-3 x *B. napus*-1	61.50**	13.33**	-1.52	17.20	8.13	-39.97**	19.34**	Complementary
ISN-706 x *B. napus*-2	51.27**	-13.00**	77.53**	77.47**	-6.80*	-108.13**	79.85**	Duplicate
B. napus (E)-1 x *B. napus-1*	*71.55***	*10.67***	-7.68	-10.75	6.33*	15.81	6.89*	*Duplicate*
B. napus (E)-2 x EC-400802	*60.28***	*13.47***	40.07**	48.20**	3.60	-72.20**	58.14**	Duplicate
Number of siliquae on main shoot								
TR-3 x *B. napus*-1	43.73**	3.60	-6.60	2.13	0.65	23.40*	25.90**	*Duplicate*
ISN-706 x *B. napus* (E)-2	47.18**	-14.40**	25.65**	31.80**	-8.37**	-69.03**	52.68**	Duplicate
B. napus (E)-1 x *B. napus*-1	41.65**	-7.36**	40.10**	47.47**	-7.39**	-67.88**	35.49**	Duplicate
B. napus (E)-2 x EC-400802	59.95**	1.16	-61.58**	-48.38**	-1.11	41.23*	*96.18***	Duplicate
B. napus-1 x EC-400802	36.68**	-4.00*	18.88	24.23*	-4.83*	-9.13	29.86**	Duplicate
EC-400802 x EC-400803	39.15**	-9.19**	18.69*	21.36**	-13.59**	-20.65	45.44**	Duplicate

Number of seeds/siliqua								
ISN-114 x EC-400803	22.32**	1.73	14.38	15.52*	-	-	4.60	-
ISN-706 x *B. napus*-2	21.94**	-1.53	10.64*	14.49**	1.38	-26.13**	23.45**	Duplicate
B. napus-1 x EC-400802	24.49**	-3.47*	9.54*	5.29	-4.35*	-3.01	9.28**	Duplicate
1000 seed weight (g)								
ISN-114 x EC-400803	3.47**	0.85**	-0.61	0.67	0.57**	-2.91**	69.69**	Complementary
TR-3 x *B. napus*-1	3.44**	0.24*	0.30	0.74**	0.26*	-1.49**	20.76**	Duplicate
ISN-706 x *B. napus*-2	3.15**	-0.19	4.52**	4.44**	-0.17	-6.33**	272.20**	Duplicate
B. napus (E)-1 x *B. napus*-1	3.86**	0.18**	0.10	-	-	-	2.73	-
EC-400802 x EC-400803	3.01**	-0.62	2.19*	2.16*	-0.62	-2.54	22.61**	Duplicate
Seed yield/plant (g)								
ISN-114 x EC-400803	15.64**	3.74	38.39**	43.26**	0.78	-90.28**	94.59**	Duplicate
TR-3 x ISN-706	18.41**	2.05	24.97**	17.59**	-0.28	-13.56	21.21**	Duplicate
TR-3 x *B. napus*-1	19.00**	14.47**	22.95**	28.03**	12.27**	-61.29**	34.45**	Duplicate
ISN-706 x *B. napus*-2	15.71**	-4.06	32.00**	40.17**	0.71	-69.23**	178.00**	Duplicate
ISN-706 x *B. napus* (E)-2	17.54**	2.21	33.06**	28.70**	3.11	-44.06**	20.77**	Duplicate
B. napus (E)-1 x *B. napus*-1	24.90**	3.39*	5.48	4.09	-0.57	21.00*	18.91**	Complementary
B. napus (E)-2 x EC-400802	20.53**	-5.30**	21.74**	14.20**	-3.02*	-7.96	48.81**	Duplicate
B. napus-1 x EC-400802	12.01**	-0.07	15.41**	16.73**	2.98	0.25	105.17**	Complementary
EC-400802 x EC-400803	13.34**	-6.97**	8.74	16.19**	-11.95**	-24.00**	123.38**	Duplicate
Oil content (%)								
ISN-114 x EC-400803	43.47**	-0.65	0.23	4.55*	-0.33	18.84**	12.83**	Duplicate
TR-3 x ISN-706	43.70**	-0.01	-2.06**	-	-	-	-	-
TR-3 x *B. napus*-1	42.68**	1.09	0.89	4.20	1.36	-98.96*	8.64**	Duplicate
GLS-1 x *B. napus* (E)-1	42.71**	0.64	-0.24	-	-	-	0.30	-
ISN-706 x *B. napus*-2	42.45**	1.16**	-1.85**	-	-	-	0.90	-
ISN-706 x *B. napus* (E)-2	43.45**	0.33	-5.82**	-4.04*	-1.36*	1.38	38.76**	Duplicate
B. napus (E)-1 x *B. napus*-1	43.19**	-1.12**	-3.57**	-	-	-	3.41	-
B. napus (E)-2 x EC-400802	41.56**	-1.75*	2.29	3.49	-0.43	-9.27*	6.66*	Duplicate
B. napus-1 x EC-400802	43.81**	0.46	-0.22	-	-	-	1.11	-
EC-400802 x EC-400803	43.08**	-0.06	-1.58	-	-	-	0.83	-

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

For number of siliquae on main shoot, seeds/siliqua, dominance and non-additive interaction were predominant whereas for 1000-seed weight was predominantly governed by additive and additive x additive effects, for seed yield, the effects were mainly dominance and additive x additive type of interaction. Similar results were reported by Badwal and Labana (1987), Singh and Mittal (1993) and Singh and Srivastava (1999). For oil content, additive and additive x dominance type of interactions were observed which is in the line of the findings of Sheikh and Singh (1998) and Verma and Kushwaha (1999) who also reported the pre-dominance of non-additive gene effects for these traits.

The additive effects and gene interaction 'I' or other type digenic complementary gene interactions can be exploited effectively by selection for the improvement of concerned characters. Use of reciprocal recurrent selection has been suggested to improve the characters when both additive and non-additive gene effects are involved in the expression of traits (Comstock *et al.*, 1949). Presence of non-additive gene actions for seed yield and oil content indicating that conventional selection procedure may not be effective enough for improvement of yield. Therefore, changes in conventional methodologies like mass selection, bulk method, pedigree method, etc., are required for achieving targeted production to satisfy the increasing oilseeds demand. Breeding procedure like biparental mating to break up undesirable linkage, recurrent selection and diallel selective mating may be useful for increasing the yield level in the oilseed crops like *gobhi sarson*.

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In vitro regeneration from cotyledonary explants of *toria* and *brown sarson* morphotypes of *Brassica rapa* ssp. *campestris* (L.) Clapman with a special reference to S-allele homozygotes

U.S. Gill, S.S. Banga, I. Ahuja, P. Chauhan and S.K. Banga

Department of Plant Breeding, Genetics & Biotechnology, Punjab Agricultural University, Ludhiana-141 004, Punjab

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Abstract

Protocols for plant regeneration from cotyledonary explants were evaluated for the purpose of multiplying advanced generation inbreds (S_5-S_8) in sporophytic self-incompatible *Brassica rapa* ssp. *oleifera*. *Toria* variety TL-15 responded best to *in vitro* shoot regeneration followed by *brown sarson* vars. Tobin and Emmer. Out of the seven different modifications of MS basal medium evaluated, maximum shoot formation was observed on M_1 (MS + 2.0 mg/l BAP + 2.0 mg/l IAA). TL-15 responded better when cotyledonary explants were harvested from 6-7 days old seedlings, whereas Tobin and Emmer showed maximum regeneration following culturing of younger (4-5 days old) explants. Media x seedling age interaction was also indicated for shoot regeneration but not for callusing. Addition of silver nitrate (2.0 mg/l) to the two most responsive culture media (M_1 and M_7) enhanced shoot regeneration significantly. Based on these results, M_1 medium supplemented with silver nitrate (2.0 mg/l) was selected for carrying out morphogenetic studies on selected S-allele homozygotes. PBT 9 S_9 was found to be the most responsive with 16.0 % shoot regeneration followed by Candle S_{15} (12.9%), Torch S_{10} (10.7%), PBT 20 S_9 (5.5%), FT 2 S_{11} (5.2%) and PBT 3 S_{20} (2.5%).

Key words: Inbreds, micropropagation, self-incompatibility, silver nitrate

Introduction

Turnip rape (*Brassica rapa* ssp. *campestris*) is an important oilseed crop of Asia and Canada. Being sporophytically self-incompatible (SI), it is highly cross-pollinated and varietal improvement mostly involves synthesis of synthetics or composites. Development of F_1 hybrids in this crop has not been possible so far due to difficulties in large scale seed multiplication of inbred parents. Micropropagation that has been successfully used in a number of crops, can theoretically provide an unending source of parental types in *B. rapa*. A number of protocols for successful micropropagation have been reported in many Brassica crops (Sharma and Bhojwani, 1990; Palmer, 1992; *Wang et al.*, 1999). Very few studies (Murata and Orton, 1987; Narasimhulu and Chopra, 1988), however, are available in *oleifera* type of *B. rapa* as it is considered to be a recalcitrant species. Availability of S-allele homozygotes in *B. rapa* vars. *toria* and *brown sarson* has now renewed interest in producing self-incompatibility based rapeseed hybrids. Further, the absence of any natural mechanism for vegetative multiplication in *B. rapa* necessitated the need to investigate vegetative explants (hypocotyl, cotyledons and leaf discs) from oilseed forms of *B. rapa* for their morphogenetic potential. In this communication development of an efficient protocol for plant regeneration from cotyledonary explants only is reported as no regeneration was observed from hypocotyls and leaf discs.

Materials and methods

The plant materials for the study comprised nine genotypes of B. rapa, which included three test-genotypes (Tobin, Emmer and TL-15) and six S-allele homozygotes (Candle S_{15}, FT 2 S_{11}, Torch S_{10}, PBT 3 S_{20}, PBT 9 S_9 and PBT 20 S_9). Surface sterilized seeds of three varieties *viz.*, Tobin, Emmer and TL-15 were cultured on half strength Murashige and Skoog (1962) medium for germination at 25±2°C temperature in darkness. Resultant four to seven days old seedlings were used as the source of cotyledonary explants. The two cotyledons from each seedling were carefully excised and cultured per test tube after removing the petiole stalk and basal portion for induction of morphogenesis in the different test media.

Induction of morphogenesis : The basal medium for the induction of morphogenesis was Murashige and Skoog's medium (MS), supplemented with BAP (1-3 mg/l), IAA (0.1-0.3 mg/l), NAA (0.2-0.5 mg/l) and $AgNO_3$ (2 mg/l) in different combinations (Table 1). About hundred cultures per treatment were maintained for morphogenesis at 25±2°C temperature, 50-60 % of relative humidity and a light intensity of about 5000 lux with 16/8 hours of light/dark conditions. Data from each explant was recorded regularly

for percentage of callusing or direct regeneration. Regenerated plantlets were transferred into MS medium supplemented with 0.2 mg/l BAP for multiplication. The shoots with one or two nodes and four or five leaves were then transferred to half MS medium with lower concentration of agar (0.5%) for rooting.

Table 1 Shoot differentiation in cotyledonary explants (pooled over days after germination) of *Brassica rapa* under different concentrations of plant growth regulators

Genotype	Medium	Cytokinin (mg/l)	Auxin (mg/l)	Shoot regeneration (%)	Shoots/regenerating explant	
					Mean ± S.E.*	Range
Tobin	M_1	BAP(2)	IAA(0.2)	7.9	4.6±0.6	3 - 8
	M_2	BAP(3)	IAA(0.2)	4.7	4.4±0.6	1 - 7
	M_3	BAP(1)	IAA(0.2)	0.0	-	-
	M_4	BAP(2)	IAA(0.3)	7.9	4.5±0.4	3 - 7
	M_5	BAP(2)	IAA(0.1)	3.1	4.3±0.5	2 - 7
	M_6	BAP(2)	NAA(0.2)	0.0	-	-
	M_7	BAP(2)	NAA(0.5)	8.8	4.7±1.1	1 - 12
Emmer	M_1	BAP(2)	IAA(0.2)	0.0	-	-
	M_2	BAP(3)	IAA(0.2)	1.6	3.4±0.5	2 - 5
	M_3	BAP(1)	IAA(0.2)	0.9	4.0±0.7	3 - 6
	M_4	BAP(2)	IAA(0.3)	1.6	4.1±0.6	2 - 7
	M_5	BAP(2)	IAA(0.1)	1.7	3.6±0.5	1 - 5
	M_6	BAP(2)	NAA(0.2)	0.0	-	-
	M_7	BAP(2)	NAA(0.5)	7.9	4.1±0.6	1 - 8
TL-15	M_1	BAP(2)	IAA(0.2)	9.3	4.0±0.5	2 - 6
	M_2	BAP(3)	IAA(0.2)	6.6	3.9±0.4	1 - 5
	M_3	BAP(1)	IAA(0.2)	2.5	4.2±0.4	3 - 7
	M_4	BAP(2)	IAA(0.3)	8.1	4.1±0.3	2 - 5
	M_5	BAP(2)	IAA(0.1)	4.6	4.8±0.4	3 - 7
	M_6	BAP(2)	NAA(0.2)	5.2	4.8±0.5	3 - 7
	M_7	BAP(2)	NAA(0.5)	5.0	4.8±0.5	3 - 7

*S.E. = Standard Error

Transfer of plantlets : The plantlets having well developed roots were taken out from the culture tubes without damaging the roots and shoots. The agar was removed from the roots and plantlets were transferred to pots containing sterilized garden soil and compost. In earlier phases of growth (7-10 days), the plants were kept under high humidity before transferring them to field conditions.

Results and discussion

Role of growth regulators : Enlargement of cotyledons was observed after one week of culturing which continued further from the cut ends to differentiate into callus or direct shoot bud formation (Fig 1a, b). Majority of the cotyledons (51%) underwent callusing whereas shoot bud formation was observed only in 4.2 %. For callusing in var. Tobin, the M4 medium (MS + BAP 2 mg/l + IAA 0.3 mg/l) yielded the best response with a mean callus induction of 74.7 %. In Emmer and TL-15, M7 medium containing BAP (2 mg/l) + NAA (0.5 mg/l) showed maximum mean callusing of 54.8 % and 66.3 % respectively (Table 1).

Shoot buds proliferated into complete shoots (Fig 1c, d). For direct shoot regeneration M_1 and M_7 media were found to be the best amongst the evaluated media whereby a maximum of 9.3 (TL-15), 8.8 (Tobin) and 7.9 (Emmer) percent cotyledons responded to morphogenesis. The mean number of shoots per regenerating explant was also higher on M_7 medium for all the three test genotypes. However in case of TL-15, the mean number (4.8) of shoots per regenerating explant was the same for M_5, M_6 and M_7 medium.

The importance of high BAP and low IAA concentrations in multiple shoot formation from cotyledonary explants as observed in present investigation is in agreement with the results reported in *B. juncea* (Goyal *et al.*, 1990) wherein BAP was found to be more effective than kinetin for inducing shoots. In general, media having BAP less than 2 mg/l responded poorly to callusing and shoot regeneration.

Genotype specificity : Each explant is endowed with all the genetic information of the donor plant and its response to *in vitro* culture depends upon its heredity. In the present study, the three test genotypes responded differently to callusing and shoot regeneration. Callusing was similar in Tobin and TL-15, but was lower in Emmer. Variety TL-15 showed maximum shoot regeneration followed by Tobin and Emmer in all the test media combinations excepting M_7 (Fig. 2) which elicited the maximum response from Tobin, followed by Emmer and TL-15. Variety Emmer did not respond to regeneration on M_1 medium. These studies suggested that despite the strong influence of heredity, the morphogenetic response could be modified within the limits of adaptability and media conditions.

Age of explant : Regenerative ability and morphogenetic response of an explant depends on its developmental stage. This aspect has mostly remained uninvestigated in *B. rapa* ssp. oleifera. From the data regarding the effect of age on regenerative ability of cotyledonary explants (Fig.3), it was apparent that in brown sarson, (Tobin and Emmer) the younger cotyledons (4-5 days old) gave the best response. In contrary, older explants (6-7 days old) appeared to have greater regenerative potential in case of *toria*, irrespective of the media composition. When average response of all the genotypes was studied collectively, it was found that seven days old explants responded best on M_1 (7.8%), M_3 (2.1%) and M_6 (5.0%) media. On the other hand, maximum shoot regeneration in M_2 (6.3%), M_4 (7.0%), M_5 (5.2%) and M_7 (8.6%) media was recorded from five days old explant. These results were suggestive of significant media x seedling age interaction. Seedling age appeared to have no influence on callusing in various media evaluated. For brown sarson (Tobin, Emmer) our results were in conformity to those reported by Palmer (1992) who recorded poor shoot regeneration response from cotyledonary explants of older seedlings. In *B. rapa* ssp. chinensis, on the other hand, almost similar level of adventitious bud induction has been reported (Xie *et al.*, 2000) from explants of younger (5 days) as well as older (9 days) seedlings. No such investigations were previously reported for *B. rapa* ssp. oleifera.

Role of silver nitrate : Poor plant regeneration following explanting has been attributed to inhibitory effect of endogenous ethylene produced in tissue cultures (Chi *et al.*, 1990). Addition of $AgNO_3$ to the culture medium improves plant regeneration as it inhibits ethylene incorporation (Beyer, 1979). A number of investigators in the past (Chi *et al.*, 1990, Palmer, 1992, Cao *et al.*, 2000) have reported a positive influence of $AgNO_3$ on plant regeneration and morphogenesis in recalcitrant Brassica types. To assess it in oleifera type of *B. rapa*, a defined concentration of $AgNO_3$ @ 2.0 mg/l was added to the two most responsive test media i.e. M_1 and M_7. A dramatic increase in percent shoot regeneration was observed following addition of silver nitrate for all the three test genotypes (Table 2). Even in Emmer, which otherwise showed no regeneration on M_1 medium, upto 32.0 % shoot regeneration was recorded following addition of silver nitrate whereas in TL-15 shoot regeneration improved from a maximum of 18.4 % to a healthy 64.1 %.

Table 2 **Effect of silver nitrate on per cent shoot regeneration (pooled over all the treatments) in three varieties of *Brassica rapa***

Medium	Tobin	Emmer	TL-15
M_1	7.9	0	9.3
$M_1 + AgNO_3$	17.5	25	43
M_7	8.8	7.9	5
$M_7 + AgNO_3$	16.7	19.24	32.17

Multiplication of S-allele homozygotes : On the basis of the results described in the preceding section, $M_1 + AgNO_3$ medium showing best regenerative response was identified for evaluating micropropagating ability of selected S-allele homozygotes (inbreds) through cotyledonary (4-7 days old) explant culture. Although percent callusing was almost similar (53-71%) in evaluated homozygotes (Table 3), large differences (2.9-16%) were observed for percent shoot regeneration.

Table 3 **Shoot regeneration (%) in S-allele homozygotes cultured under $M_1 + AgNO_3$ medium**

S-allele homozygotes	Shoot regeneration (%)	Shoots/regenerating explant	
		Mean±S.E.*	Range
Candle S_{15}	12.9	4.3±0.5	2-7
Torch S_{10}	10.7	4.6±0.5	1-6
FT 2 S_{11}	5.2	3.9±0.4	1-5
PBT 3 S_{20}	2.9	4.7±0.4	2-6
PBT 9 S_9	16.0	5.1±0.6	2-8
PBT 20 S_9	5.5	3.7±0.3	1-5

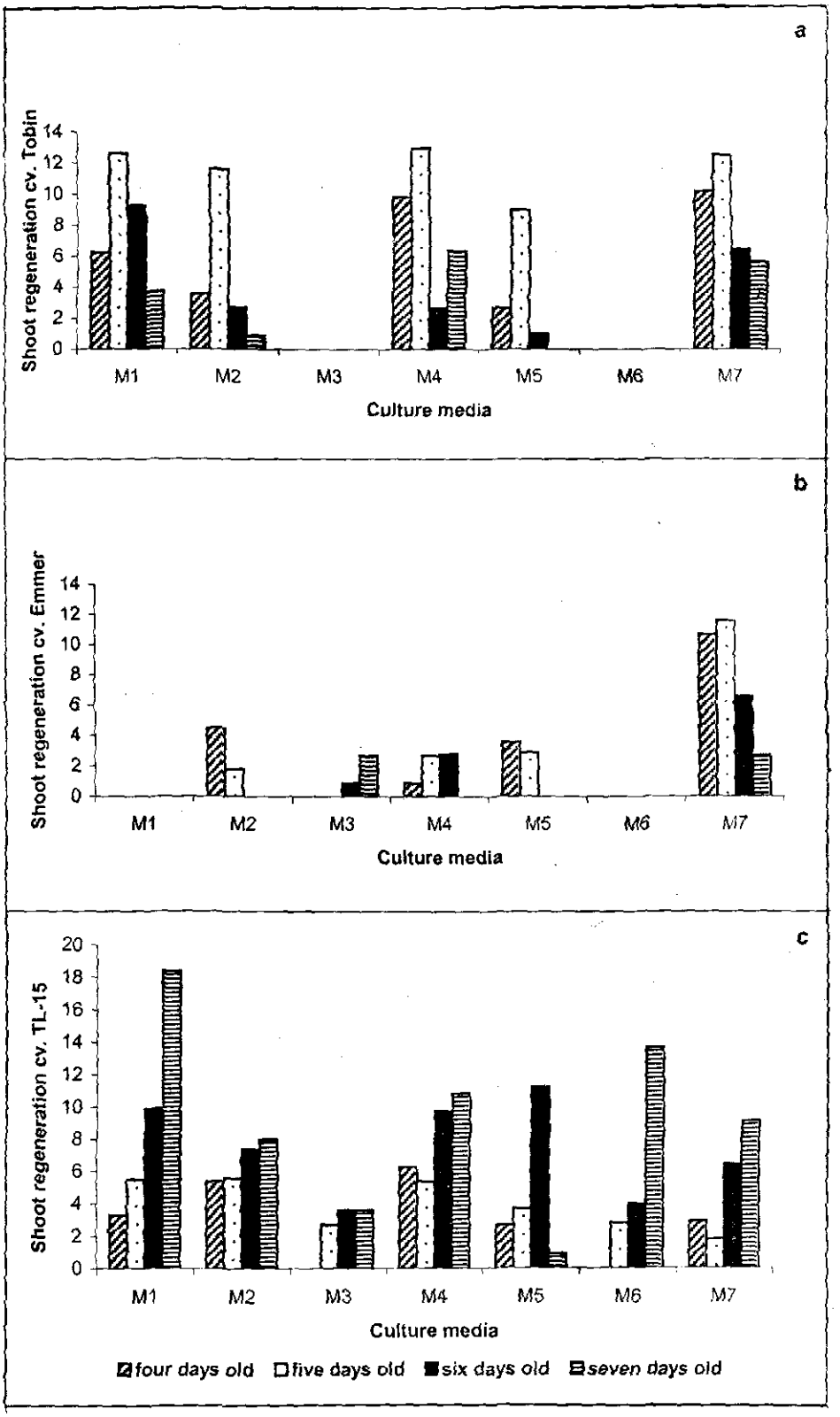

Fig. 2. Effect of age of cotyledonary explants on percent shoot regeneration in *Brassica rapa* cv. Tobin (a), Emmer (b) and TL-15 (c).

Also S-allele homozygotes were less responsive to shoot regeneration than open pollinated cultivars as only a maximum of 16 % shoot regeneration was observed as against 64.1 % in var. TL-15. Mean values for the number of shoots per regenerating explant varied from 3.7 (PBT 20 S_9) to 5.1 (PBT 9 S_9). A maximum of eight shoots was obtained from PBT 9 S_9 explants. The *toria* type S-allele homozygote PBT 9 S_9 and *brown sarson* type Torch S_{10} appeared especially suited for use as female lines in hybrid seed production due to their greater shoot regeneration potential and hence the multiplication rate.

The studies demonstrated the feasibility of using micropropagation as a mean of supplying a large number of identical parental inbreds necessary for hybrid seed production which otherwise is difficult in self-incompatible *B. rapa*. Studies also emphasized the importance of genotypic and environmental determinants for eliciting maximum regenerative response.

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Studies on combining ability analysis and physiological parameters under rainfed conditions in castor, *Ricinus communis* L.

S.S. Solanki

Agricultural Research Station, Rajasthan Agricultural University, Mandor, Jodhpur-342 304, Rajasthan

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Abstract

Combining ability analysis in castor through 8 x 8 diallel study (excluding reciprocals) was carried out over two rainfed environments indicated that both *gca* and *sca* were influenced by environments. The estimated ratio of variances *gca* and *sca* indicated preponderance of non additive gene effects for the inheritance of days to 50 % flowering and seed yield. Whereas effective length of primary raceme, capsules on primary raceme and 100 seed weight were mainly governed by additive gene effects. MI-61 was identified as good general combiner for capsules on primary raceme and seed yield under rainfed conditions (light textured soil). BM-8-11-2-97 was found good general combiner for 100-seed weight while RG-125 for days to 50% flowering of primary raceme. Physiological parameters indicated that DCS 9 adopted water spending nature to tolerate drought. Low values for leaf conductance and rate of transpiration in line JI-220 indicated its drought tolerance capacity. Segregating generation of crosses JI-220 x MI- 61and JI- 220 X DCS-9 may be handled to develop superior varieties/ male combiner suitable for rainfed conditions. Use of reciprocal recurrent selection and consideration of physiological parameters is suggested to develop drought tolerance genotypes.

Key words: Genotype x environment, gene effects, leaf conductance, transpiration

Introduction

Castor (*Ricinus communis* L.) is cultivated as rainfed crop mainly in Southern peninsular region and under irrigated condition in the states of Gujarat and Rajasthan. In some pockets of Rajasthan castor is grown under rainfed situation. Seed yield under rainfed conditions is very low as compared to irrigated situations mainly due to poor soil fertility and low moisture retention capacity. Thus, to develop superior genotypes \ male combiners to be used in breeding program it is essential to test combining ability under rainfed conditions over environments. Besides this, information on physiological parameter *viz.*, leaf conductance, rate of transpiration and leaf temperature are useful in identification of parents and cross combination to be handled for the development of drought tolerant genotypes. Therefore, the present experiment was taken up to test the combing ability of parents and crosses of castor under rainfed condition over environments to generate information on physiological parameters, in the light textured soil.

Materials and methods

Parents namely, GC-2, DCS-9 (released varieties) JI-220, LN.94-3, MI-61, F8-90-1-98, BM-8-11-2-97 (advanced lines) and a germplasm line RG-125 (exotic) were used for the present experiment. The parents were diverse in respect of morphological characteristics. Parents were crossed in diallel mating design excluding reciprocals. Parents and crosses were evaluated under rainfed condition. Experiments were laid out in Randomized Block Design with three replications under two environments. The parents and crosses were randomized separately in each replication. The environments were created through dates of sowing 18-7-2000 and 25-7-2000 and adopted crop geometry of 90x 45cm and 90x 60 cm respectively. The soil of the experiment plot was loamy sand in texture and slightly alkaline (pH 8.3) in reaction. The soils were poor in nitrogen (170kg/ha) and phosphorus (19.4 kg/ha) availability but were high in potassium (347 kg/ha) status. The available soil moisture was low (at 0.3 atmosphere 9.2 % and at 15 atmosphere 3.2 %) and bulk density of soil was 1.79 g/cc, during crop season 105 mm rainfall was received. Observations on seed yield/plant, days to 50 % flowering of primary raceme, effective length of primary raceme, 100-seed weight and number of capsules on primary raceme were recorded on five randomly selected competitive plants. Data were subjected to standard statistical methods for analysis of variances. Combining ability analysis over environments was computed as suggested by Griffing's(1956) method 2 model 1 and Singh (1973 ; 1979).

Observations on physiological parameters were recorded in selected parents and crosses. The physiological parameters i.e., stomatal/leaf conductance (g), transpiration rate (TR) and leaf temperature were recorded in morning (0800 hrs), noon (1200 hrs) and evening (1600 hrs) with the help of Steady State Porometer (LICOR, USA). The observations were recorded on three plants in each genotype. Empirical indices computed using maximum value of 'g' and TR as one hundred, categorizes, materials on transpiration observations into three groups, water saver (0-33), moderate water spender (34-66) and high water spenders (67-100).

Results and discussion

The analysis of variances for characters under study showed highly significant mean squares due to genotypes and its sub division. It indicated presences of genetic variability among the parent and hybrids. Significant genotype x environment inter action for all the traits clearly justifies the testing of the material under more than one environment. Sub division of genotype x environment interaction indicated the differential response of parents as well as hybrids to changing environment. Lower magnitude of hybrids x environments interaction as compared to parent x environment inter action was observed for 100 seed weight, capsules on primary raceme and seed yield. It revealed higher sensitiveness of parents for seed yield and other important yield contributing characters.

Combining ability analysis indicated significant mean squares due to general and specific combining ability (*gca*); it revealed the importance of both additive and non additive gene effects in inheritance of traits studied (Table1). Significant *gca* x Env. and *sca* x Env. indicated that both additive as well as non additive gene effects were sensitive to environmental changes. The estimated variances of combining ability indicated the preponderance of non additive gene effects for the seed yield and days to 50 % flowering of primary raceme. Whereas additive gene effects governed the main role in the inheritance of effective length of primary raceme, number of capsules on primary raceme and 100 seed weight. The results obtained in present study were in agreement with Solanki and Joshi (2000), except days to 50 % flowering of primary raceme. Inheritance of gene effects involved for expression of days to 50% flowering is reported for the first time.

The estimates of the *gca* showed that MI-61 was the best general combiner for the seed yield/plant and number of capsules on primary raceme (Table 2). MI-61 was also good general combiner for the 100 seed weight and effective length of primary raceme. Such line possessing additive gene effects for seed yield and important yield contributing characters is highly desirable for breeding programme. Bold seeded as well as early parent, BM-8-11-2-97(48-1 x RCG-10) was identified as good general combiner for 100 seed weight. It recorded only 11 nodes to primary raceme and 43 days to 50 % flowering of primary raceme however its general combining effects for days to flowering were not in the desirable direction. This might be due to a late type genotype in back ground (48-1) of development of this line. Another early and bold seeded germplasm line RG125 was good general combiner for days to 50% flowering of primary raceme. Variety DCS 9 as well as an advance line JI-220 were other good combiner for seed yield. In general *per se* performance of parents was good indication of their *gca* effects except in case of seed yield. Similar results for seed yield were reported by Dobariya *et al.* (1992).

Estimates of *sca* were significant in 13 crosses, based on *sca* and *per se* performance for seed yield crosses JI-220 x MI-61, JI- 220 x DCS-9, LN94-3 x MI-61, and MI 61x F-8-90-1-98 were identified as desirable crosses (Table 3). These crosses exhibited significant heterosis over better parent and also depicted significant sca effects for some yield contributing characters. In crosses, JI-220 x MI-61, JI- 220 x DCS-9, and MI 61x F-8-90-1-98 both parents involved were good general combiners for seed yield. It revealed the presence of additive x additive type of gene action for inheritance of seed yield in these crosses, which is likely to provide transgressive segregates in early segregating generations.

Table 1 Analysis of variance for combining ability analysis pooled over environments for seed yield and other traits in castor

Source	DF	Days to 50 % flowering	Effective length of primary raceme	Number of capsules on primary raceme	100 seed weight	Seed yield /plant
GCA	7	140.0 **	398.9 **	1571.6**	264.8**	471.5**
SCA	28	41.8 **	26.2 **	69.9**	7.6**	115.3**
Environments	1	1102.7**	520.1**	3883.2**	96.0**	11573.4**
GCA x Env.	7	41.4 **	5.8	329.3**	21.8**	141.0**
SCA x Env.	28	38.5 **	15.0**	140.0**	7.9**	91.5**
Error	140	3.3	2.9	2.26	0.98	3.5
Estimates						
σ^2 *gca*		6.8	19.8	78.6	13.2	23.6
σ^2 *sca*		19.2	11.7	33.8	3.3	55.9
σ^2 *gca* : σ^2 *sca*		0.35	1.70	2.32	3.98	0.42

** Significant at P = 0.01

Table 2 Estimates of general combining ability over environments for seed yield and other traits

Parent	Days to 50 % flowering of primary raceme	Effective length of primary raceme	Number of capsules on primary raceme	100 seed weight	Seed yield/ plant
GC 2	0.23	2.07**	1.64**	-3.45**	-3.99**
JI 220	1.32*	4.64**	10.83**	-3.70**	4.10**
LN.94-3	-1.37*	-3.70**	-8.46**	1.60**	-4.06**
DCS 9	5.40**	3.46**	3.75**	-2.30**	3.93**
MI 61	-0.71	3.79**	10.99**	2.40**	6.40**
F8-90-1-98	-1.30*	1.38*	2.17**	-3.40**	2.64**
BM 8-11-2-97	0.16	-4.38**	-10.47**	5.55**	-2.10**
RG 125	-3.73**	-7.26**	-10.45**	3.30**	-6.92**
gi ±	0.39	0.35	0.31	0.20	0.39

* Significant at P = 0.05 and ** Significant at P= 0.01

Table 3 Seed yield, heterosis (BP) and sca effects for yield and other characters in castor

Cross	Seed yield/ plant (g)	Heterosis over better parent (%)	sca effects				
			Seed yield	100 seed weight	Days to 50% flowering	No. of capsules on primary raceme	Effective length of primary raceme
GC 2 x MI 61	35.4	61.7**	8.1**	-1.1**	-3.5**	3.9**	1.6
GC 2 x BM-8-11-2	23.0	27.6	4.2**	-1.8**	-2.9*	0.7	-2.0
JI 220 x DCS 9	40.0	34.4**	7.1**	-0.01	-3.0**	-0.4	4.3**
JI 220 x MI 61	50.9	132.4**	15.5**	-1.9**	-0.05	-1.2	-2.7*
JI 220 x F 8-90-1-98	36.6	24.5**	4.9**	-1.1*	-7.8**	3.8**	0.4
JI 220 x BM 8-11-2	31.1	51.1**	4.3**	1.6*	3.5**	-6.3**	4.6**
LN94-3 x DCS 9	28.0	-5.8	3.2**	-0.4	-2.9*	2.6**	3.3**
LN94-3 x MI 61	39.5	80.6**	12.3**	1.4**	-1.3	-0.2	-3.3**
LN94-3 x F-8-90-1-98	28.3	-3.8	4.8**	-0.4	-3.5**	-4.2**	-5.4**
LN94-3 x BM 8-11-2	23.4	162.3**	4.7**	0.8	-0.5	10.4**	2.5*
DCS 9 x BM 8-11-2	33.3	11.9	6.6**	-3.2**	-2.1*	-2.7**	-0.01
MI 61 x F-8-90-1-98	38.9	32.5**	5.0**	-1.8**	-0.6	-4.3**	-2.1
BM 8-11-2 x RG-125	23.2	159.1**	7.3**	-0.6	0.2	5.2**	1.1
sij			1.19	0.64	1.17	0.96	1.1

Observations on physiological parameters indicated that, amongst parents DCS-9 (double bloom) recorded high seed yield and exhibited highest stomatal conductance and transpiration rate (Table 4). This might be due to high water absorption on account of its strong root system or due to its double bloom nature favouring high rate of transpiration or developmental reasons. Since variety DCS-9 was developed under high rainfall environmental conditions of southern peninsular region thus adopted water spending nature drought avoidance mechanism, as indicated by its high seed yield in spite of higher values recorded for stomatal conductance and transpiration rate. The advance lines MI-61 and LN-94-3 were found to be moderate water spender genotypes indicating their suitability for rainfed as well as irrigated conditions. The advance line JI-220 recorded least values for physiological parameters studied. The low values of leaf conductance, rate of transpiration and leaf temperature in line JI-220 might be due to its triple bloom nature and better water use efficiency under harsh climatic conditions. Hence it was considered as drought tolerant genotype and falls under water saver category.

Genotype, BM-8-11-2-97 was found to be high water spender, though it is an early and dwarf genotype. High water spender nature of this genotype might be due to its higher requirement of photosynthate assimilates for development of bold seed (seed weight 41.5 g) or morphological characteristics *viz.*, double bloom and non spiny nature.

Table 4 Leaf conductance, transpiration rate and leaf temperature in castor

Genotype	Seed yield/plant (g)	Leaf conductance		Rate of transpiration		Leaf temperature	
		Average*	Index	Average *	Index	Average *	Index
JI 220	18.9	178.67	41.07	4.74	42.13	24.4	89.3
LN 94-3 MP98	8.3	229.57	52.77	6.21	55.19	24.9	91.0
DCS 9	29.7	400.08	91.97	10.93	97.15	27.2	99.5
MI 61	21.9	209.75	48.21	6.00	53.33	26.1	95.5
BM8-11-2-97	8.9	284.89	65.49	7.87	69.95	25.7	93.8
JI 220 x LN 94-3	20.4	322.22	74.07	9.22	81.95	26.6	97.1
JI 220 x DCS 9	40.0	251.97	57.92	6.88	61.15	26.9	98.2
JI 220 x MI 61	50.9	304.58	70.02	8.15	72.44	26.5	96.9
LN 94-3 x MI 61	39.6	375.48	86.32	9.59	85.24	26.6	97.3
LN 94-3 x BM 8-11-2-97	23.4	295.18	67.86	8.87	78.84	24.1	88.3
LN 94-3 x DCS 9	28.0	435.00	100.00	11.25	100.00	26.8	97.8
DCS x MI 61	29.4	216.28	49.72	5.87	52.17	27.4	100.0
DCS 9 x BM 8-11-2-97	33.3	320.02	73.56	8.83	78.48	26.3	96.1
MI 61 x BM 8-11-2-97	23.6	224.92	51.70	6.00	53.33	26.6	97.1

* = Average of observations recorded in morning, noon and evening

In general high leaf temperature resulted in high rate of transpiration in castor. Increase in rate of transpiration with increase in temperature was also reported in castor by Dai, Edward and Ku (1992).

Plant water relationship study of crosses indicated no definite pattern of relationship between parents and crosses to understand drought tolerance study on inheritance of bloom including quantification of wax in parents and crosses and other physiological parameters (water absorption, leaf conductance, rate of transpiration, root study and relative water content and biochemical aspect) is suggested. Considering per se performance for seed yield and rate of transpiration categories, crosses JI-220 x DCS-9, DCS-9 x MI-61 and MI-61 x BM-8-11-2-97 were important under moderate water spender category and crosses JI-220 x MI-61 were also better though representing high water spending group.

It was concluded that genotype MI-61, JI-220 and DCS-9 were good general combiners for seed yield and also have better water use efficiency under light textured soil. Thus, these genotypes can be used in breeding programme for the development of superior genotypes for rainfed conditions. Segregating generation of cross JI-220 x MI-61 and JI-220 x DCS-9 may be handled to develop superior varieties/male combiners for rainfed areas of light textured soil. Presence of additive x additive gene action in these cross combinations for seed yield is likely to provide transgressive segregates in early generations. Reciprocal recurrent selection may be used to exploit additive as well as non additive gene effects and physiological parameters are also useful in identification of parents and crosses for development of drought tolerant genotypes.

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Genotype x environment interaction and stability parameters in castor, *Ricinus communis* L.*

J.B. Patel and H.C. Pathak

Department of Agricultural Botany, J.V. College, Baraut, Baghpat-250 611, U.P.

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Abstract

Genotype x environment (G x E) interaction and stability parameters of 65 genotypes consisting of 50 F_1 hybrids resulting from 5 x 10, 'Line x Tester' mating design along with parents were studied to know the nature and magnitude of genotype x environment interaction and stability in performance for seed yield/plant and 10 other yield contributing characters. It was observed that G x E (linear) component was significant for all the traits studied except days to 50 per cent flowering, days to 50 per cent maturity and oil content whereas the pooled deviation, a non-linear component was significant for days to 50 per cent flowering, days to 50 per cent maturity, length of main raceme, number of capsules on main raceme and 100-seed weight. The results indicated that both linear and non-linear components of genotype x environment interaction were responsible for the differences in the stability of genotypes observed. Among parents, Geeta and SKP-5 were found to be stable for seed yield/plant and also for number of capsules on main raceme, number of effective branches/plant and total number of branches/plant. As many as 20 hybrids having high seed yield/plant along with non-significant linear and non-linear components were considered stable hybrids for seed yield/plant over environments, out of which, SKP-5 x SKI-73 (304 g), Geeta x 116-1 (299 g) and SKP-5 x SKI-107 (280 g) were the most outstanding hybrids which could be thoroughly tested over space and time before their exploitation for commercial cultivation.

Key words: Stability, G x E interaction, regression coefficients

Introduction

A phenotype is the product of interplay of genotype and its environment. A specific genotype does not exhibit the same phenotype under the changing 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 breeder in judging the real potential of a genotype when grown in different environments. The existence of interaction between genotype and environment has been recognized by Fisher and Mackenzie (1923). Several workers considered G x E interactions as linear functions 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 (Eberhart and Russell, 1966; Finlay and Wilkinson, 1963; Perkins and Jinks, 1968). In 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 the performance of different genotypes. G x E interaction in castor was studied by Hira Chand *et al.* (1982) and Laureti (1995).

Materials and methods

The experimental material comprised 65 genotypes consisting of 50 F_1 hybrids resulting from a Line x Tester mating design involving 5 pistillate lines (Geeta, VP-1, SKP-5, SKP-72 and SKP-93) and 10 male parents (VI-9, 48-1, 116-1, SPS-43-3, DCS-9, SH-72, SKI-73, SKI-107, SKI-80 and SKI-168). The experimental material was grown in Randomized Block Design with three replications in four environments during *kharif*, 1997-98. Environments were created by two different dates of sowing (normal *kharif* i.e., 1st week of August and late *kharif* i.e., 1st week of September) at two different locations *viz.*, Potato Research Station, GAU, Deesa and Agricultural Research Station, GAU, Talod. Each genotype was grown in a single row of 12 plants each with inter and intra row spacing of 90 cm x 60 cm. The recommended package of practices for irrigated conditions were adopted to raise the crop. The observations were recorded on five randomly selected plants for each treatment in each replications and in each environments for seed yield and its components (Table 1). The data were analyzed for variance and pooled analysis as suggested by Panse and Sukhatme (1976). The stability analysis was carried out according to the method suggested by Eberhart and Russell (1966) and described

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as per Mehra and Ramanujan (1979) and Singh and Singh (1980).

Results and discussion

Significant differences among genotypes (Table 1) pooled over environments indicated the considerable amount of genetic variability among the genotypes for all the characters studied. The genotype x environment interaction was significant for all the characters, which indicated the differential response of the genotypes under different environments. Hence, the data were subjected to stability analysis following the statistical model suggested by Eberhart and Russell (1966) to get information on the stability and adaptability of individual genotypes. Significant mean sum of squares due to genotypes, environments and environments (linear) for all the traits indicated significant variation among genotypes and environments (Table 2). The G x E interactions were significant for all the characters except seed yield/plant, number of nodes upto main raceme and oil content which suggested that genotypes interacted differently to different environments. The genotypes manifested genetic differences for their regression on environmental index as evident from the significance of G x E (linear) component for seed yield/plant, plant height, numb er of nodes upto main raceme, length of main raceme, number of capsules on main raceme, number of effective branches/plant, total number of branches/plant and 100-seed weight. The variances owing to pooled deviation were significant for days to 50% flowering and maturity, length of ain raceme, number of capsules on main raceme and 100-seed weight, indicating the involvement of non-linear component for the differences in the stability among genotypes for these traits.

Phenotypic stability of the genotypes was measured by three parameters viz, mean performance over environments ($\bar{x}$), regression coefficient (bi) and deviation from regression (S2di) (Eberhart and Russell, 1966). Breese (1969) and Paroda and Hayes (1971) emphasized that linear regression should simply be regarded as a measure of the response of particular genotype, whereas deviation from regression should be considered as measure of stability. The genotypes were classified into four different groups according to the methodology suggested by Mehra and Ramanujan (1979) and Singh and Singh (1980). The data showed that as many as 22 genotypes (2 parents and 20 hybrids) were found to be stable for seed yield/plant, which expressed high seed yield/plant, non-significant linear (b_i) and non-linear components (S^2d_i). These hybrids were also found to be stable for important yield components i.e., 12 hybrids each for length of main raceme and number of capsules on main raceme, 6 hybrids for number of effective branches/plant, 10 hybrids for total number of branches/plant and 25 hybrids for 100-seed weight were observed to be stable. The data also revealed that 9 genotypes (Geeta x VI-9, Geeta x 48-1, Geeta x SPS-43-3, Geeta x SKI-73, Geeta x SKI-107, Geeta x SKI-168, SKP-5 x 48-1, SKP-5 x SH-72 and SKP-72 x SKI-80) were found to be stable under favourable environments having high seed yield/plant, significant regression coefficient ($b_i > 1$) and non-significant deviation from regression, whereas 2 genotypes 'SKP-5 x 116-1' and 'SKP-93 x SKI-80', were found to be stable for unfavourable/poor environments having high seed yield/plant, significant regression coefficient ($b_i < 1$) and non-significant deviation from regression. The performance was unpredictable for only a single genotype (VP-1 x SKI-168) due to their significant deviation from regression.

Two stable parents and 20 stable hybrids for seed yield/plant are listed in Table 3 along with their seed yield/plant, regression coefficient (b_i), deviation from regression (S^2d_i) and various component traits for which they showed stability. The results revealed that among the parents, the highest yielding parents, Geeta (299 g) and SKP-5 (276 g) were found to be stable for seed yield/plant and also for number of capsules on main raceme, number of effective branches/plant and total number of branches/plant showing high mean along with non-significant regression coefficients and deviation from regression. Geeta and SKP-5 were the parents of three best hybrids (Geeta x SKI-107, Geeta x VI-9 and SKP-5 x SKI-73) with respect to seed yield/plant. Its utilization in plant breeding would be useful in boosting the yield in castor. Among the hybrids, SKP-5 x SKI-73 (304 g), Geeta x 116-1 (299 g) and SKP-5 x SKI-107 (280 g) were the three most outstanding stable hybrids. In general, most of the hybrids identified as stable for seed yield/plant also showed stability for one or more important component traits like length of main raceme, number of capsules on main raceme, number of effective branches/plant, total number of branches/plant and 100-seed weight. This indicated that stability of various component traits might be responsible for the observed stability of various hybrids for seed yield/plant. Hence, chances of selection of stable hybrids for seed yield/plant could be enhanced by selecting for stability for yield components. Grafisu (1959) also observed that stability of seed yield might be due to the stability of various yield components.

Table 1 Analysis of variance (mss) for different characters pooled over environments in castor

Source of variation	d.f.	Seed yield/plant (g)	Days to 50% flowering	Days to 50% maturity	Plant height (cm)	No. of *nodes upto* main *raceme*	Length of *main* raceme *(cm)*	No. of *capsules* on main *raceme*	No. of *effective* branches/ *plant*	Total No. of branches/ plant	*100*-seed weight (g)	*Oil content* (%)
Environments (E)	3	154726.03**	310.33**	353.97**	2531.32**	36.1099	2883.93**	735.21**	85.55**	65.24**	74.85**	6.16**
Genotypes (G)	64	*17368.16***	40.98**	150.80**	5261.54**	32.53**	*1327.99***	*2476.20***	*10.60***	*18.62***	*57.53***	*0.74***
G x E	192	*2427.45***	13.71**	19.09**	110.24**	1.48**	53.34**	94.22**	1.29**	1.43**	12.16**	0.27**
Pooled error	512	291.95	1.69	1.50	17.22	0.25	5.19	6.91	0.16	0.30	2.12	0.08

*, ** indicate significance at P = 0.05 and P = 0.01 levels, respectively.

Table 2 Analysis of variance (mss) for phenotypic stability for different characters *in castor*

Source of variation	d.f.	Seed yield/plant (g)	Days to 50% flowering	Days to 50% maturity	Plant *height* (cm)	No. of *nodes upto* main *raceme*	Length of *main* raceme *(cm)*	No. of *capsules* on main *raceme*	No. of *effective* branches/ *plant*	Total No. of branches/ plant	*100*-seed weight (g)	*Oil content* (%)
Genotype (G)	64	5789.17**	13.66**	50.24**	1753.87**	10.84**	442.67**	825.42**	3.53**	6.21**	19.18**	0.24**
Environments (E)	3	*51569.35***	*103.47***	*117.43***	*844.57***	*12.00***	961.40**	245.42**	28.53**	21.74**	24.96**	2.05**
Genotype x Environments	192	809.27	4.57**	6.39**	36.74**	0.49	17.78**	31.40**	0.43**	0.48**	4.05**	0.09
Environments (linear)	1	154707.94**	310.32**	353.84**	2532.17**	35.97**	3884.66**	736.49**	85.58**	65.24**	74.93**	6.12**
Genotype x *Environments* (linear)	64	1389.96**	3.30	3.49	71.96**	0.84**	32.99**	53.88**	1.01**	0.90	5.49**	0.10
Pooled deviation	130	*510.94*	5.12**	7.71**	*18.84*	0.32	10.01**	19.85**	0.14	0.26	*3.28***	*0.08*
Pooled error	512	691.97	1.69	1.47	17.21	0.25	5.19	6.90	0.16	0.30	2.12	0.08

*, ** indicate significance at P = 0.05 and P = 0.01 levels, respectively.

Table 3 Stable parents and hybrids for seed yield and component traits in castor

Genotypes		Seed yield/ plant (g)	b_i	S^2d_i	Component traits showing stability
Parents					
	Geeta	289	1.17	-109.76	CR, EB, TB
	SKP-5	276	*1.53*	*122.23*	*CR, EB, TB, O*+
Hybrids					
	SKP-5 x SKI-73	304	1.09	-190.83	DF, DM, O
	Geeta x 116-1	299	1.85	332.69	LE++, CR+, EB+, TB+
	SKP-5 x SKI-107	280	1.45	614.94	DM, NN++, CR, O
	SKP-5 x DCS-9	276	1.02	206.21	DF, DM, PH, NN, LR+, EB+, TB+, TW, O
	VP-1 x SKI-107	273	1.43	302.50	DF+, DM, PH++, NN, EB
	VP-1 x SKI-80	272	0.05	1345.87	DF, DM, PH, NN, LR+, CR+, EB++, TB, O
	SKP-72 x SH-72	272	1.73	168.60	NN+, LR++, CR
	SKP-72 x 48-1	270	1.36	226.10	NN+, LR, EB+, TW, O
	SKP-93 x SH-72	264	1.34	-9.68	PH++, NN, TW
	VP-1 x SKI-73	263	1.24	793.51	*DF, DM, PH+, NN, LR, EB+, TB+, O*++
	SKP-5 x SPS-43-3	263	1.58	437.20	LR++, TW, O
	Geeta x DCS-9	262	*0.59*	*669.74*	*PH, NN, TB++, O*
	SKP-93 x VI-9	262	0.82	206.06	DF+, PH, NN, CR, TW
	SKP-72 x SKI-107	255	0.65	-109.77	PH+, LR, CR
	Geeta x SKI-80	252	0.93	816.80	LR++, EB+, TB+, TW, O
	SKP-72 x VI-9	252	1.14	-212.66	PH++, EB+, TB+, TW, O
	SKP-72 x DCS-9	251	1.65	1367.89	DF, EB+, TW, O
	SKP-5 x VI-9	250	0.87	-161.19	DF, DM, O
	VP-1 x SH-72	249	0.86	-96.70	DF, PH++, NN++, O
	SKP-93 x SKI-107	248	0.59	592.22	PH, NN, TW+
	GCH-4	245			
Environment mean		247			
SEm±		13.1			

+, ++ indicate stability for favourable and unfavourable environments, respectively.
DF = Days to 50% flowering, DM = Days to 50% maturity, NN = Number of nodes upto main raceme; LR = Length of main raceme, CR = Number of capsules *on main raceme; EB = Number of effective branches/plant; TB = Total number of branches/plant; TW = 100-seed weight and O = Oil content*

Three hybrids *viz.*, SKP-5 x SKI-73 (304 g), Geeta x SKI-107 (323 g) and SKP-5 x 116-1 (262 g) are highly responsive to average, favourable and poor environments, respectively will further be tested over time and space before commercialization for increasing the productivity of castor under irrigated condition.

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Line x Tester analysis for seed yield and its components in castor, *Ricinus communis* L.

A.K. Kanwal, F.P. Chaudhary, K.N.Chaudhary and R.F. Chaudhary

Department of Plant Breeding and Genetics, Gujarat Agricultural University, Sardarkrushinagar-385 506, Gujarat

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Abstract

A line x tester set was obtained by crossing 5 pistillate lines as females with 10 diverse males in castor during *Rabi*, 1999-2000. The resultant hybrids along with their parents were evaluated during *kharif*, 2000-2001. Non-additive gene action was predominantly involved in the expression of most of traits like days to 50% flowering, plant height, number of nodes up to main raceme, number of capsules on main raceme, total number of branches/plant, oil content and seed yield/plant. Where as, additive gene action is predominantly involved in the expression of days to maturity, length of main raceme, number of effective branches/plant and 100 seed weight. Pistillate parents SKP 72, SKP 6 and male parents SKI 217, SKI 218 were good general combiners for seed yield per plant and length of main raceme. Male parents SKI 217 and SKI 218 were good combiners for yield, oil content, and number of capsules on the main raceme. These parents can be used in crossing and further exploited for improvement of traits in the population. The crosses SKP 72 x 48-1, SKP 4 x SKI 218 and SKP 6 x JI 263, involving good x good and good x poor general combiners respectively, with significantly high combining ability effects for seed yield per plant can be further exploited for developing superior genotypes in castor. According to *per se* performance female parents SKP 106, SKP 49; male parents SKI 217, SKI 218 and crosses SKP 72 x 48-1 and SKP 6 x SKI 218 showed high seed yield/plant along with good length of main raceme and more number of capsules/plant.

Key words: *Combining ability, line x tester analysis, Ricinus communis*

Introduction

Seed yield is the final result of the interaction of number of interrelated attributes. Constant efforts to improve yield through hybridization and selection of the parents for hybridization programme are important in crop improvement programmes. An understanding of genetic architecture of quantitative characters in the light of gene action involved in their inheritance and combining ability is essential in identifying the superior parents for use in breeding programme and superior crosses to capitalize the *gca* and *sca* effects in castor crop improvement. In view of this line x tester analysis study was undertaken, involving 5 females and 10 diverse males of castor. Combining ability analysis was carried out by the method given by Kempthorne (1957).

Material and methods

The experimental material comprised of 50 F_1 hybrids, derived by crossing 10 diverse males (SKI 160, SKI 217, SKI 218, JI 244, JI 258, JI 263, 48-1, DCS 9, DCS 47 and RG 737) with 5 females (SKP 4, SKP 6, SKP 49, SKP 72 and SKP 106) (100 % pistillate lines) and all the 15 parents. The experiment was laid out in a Randomized Block with 3 replications at College Instructional Farm, Department of Agronomy, C. P. College of Agriculture, Gujarat Agricultural University, Sardarkrushinagar, during *kharif*, 2000 - 2001. The characters studied were days to 50% flowering, days to maturity, plant height, number of nodes up to main raceme, length of main raceme, number of capsules on the main raceme, number of effective branches/plant, total number of branches/plant, seed yield/plant, weight of 100 seeds and oil content.

Results and discussion

The analysis of variance (Table 1) for combining ability indicated that the mean square due to females were significant for all the traits except for the seed yield/plant, whereas, for males it was found significant for all the characters. Further, the variance due to testers was higher than that of lines for all the characters except for the days to maturity and oil content. Females x males interaction were significant for all the characters except for days to 50% flowering, which indicates that experimental material possessed considerable variability. Non-additive component played greater role in the inheritance of seed yield, days to flowering, plant height, number of nodes, number of capsules on main raceme, total number of branches and oil content. These results are in accordance with the findings of Pathak *et al.* (1989), Dobaria *et al.* (1992), and Patel (1997). On the other side, additive gene

action played greater role in the inheritance of days to maturity, length of main raceme, number of effective branches/plant and 100 seed weight. Similar results were also reported by Dangaria *et al.* (1987), Pathak and Dangaria (1987), Patel (1997) and Thatikunta *et al.* (2000).

The estimates of combining ability effects (Table 2) indicated that SKP 6 was the most desirable female which contributed significant positive gca effects for seed yield, length of main raceme, number of capsules on main raceme. Among male parents SKI 217 was the best general combiner for seed yield, number of capsules on main raceme and oil content. These can be utilized in evolving high productive hybrids. Besides SKI 218 for length of main raceme, 48-1 for 100 seed weight, and DCS 9 for early flowering, short plant height, less number of nodes and higher number of effective branches had significant gca effects in desired direction, suggesting that these lines are good combiners as a source of genes for respective characters. Since early flowering, early maturity, short plant height and low number of nodes are desirable traits, parents with negative *gca* effects should be preferred for these characters. It was observed that SKP 106 and DCS 9 were the best parents for these traits, since they have highly significant negative *gca* effects for days to flowering, maturity, plant height and number of nodes. These observations further emphasize the need for the selection of genotypes forming spikes at lower nodes to evolve early maturing varieties/hybrids.

Hybrids showing high *per se* performance for yield and yield attributing characters involved either SKI 217 and/or SKI 218 and/or SKP 6 parent. These genotypes had also desirable *gca* effects for seed yield, length of main raceme, number of capsules on main raceme and oil content. Therefore, these genotypes can be helpful in further breeding programme to improve yield potentiality.

The best three crosses on the basis of mean performance were compared with those having significant *sca* effects in desirable direction for each character (Table 3). Nine crosses with significant *sca* effects for a character appeared also among the best three crosses selected on the basis of mean performance. In general, the crosses showing high *sca* effects had high mean performance. In most of the cases, for most of the characters as the best specific cross combination and for various character manifested the maximum or near to maximum heterosis for these characters. The present findings are in accordance with the results of Patel (1996). The significant positive or negative *sca* effects showed by the crosses involved either good x good, good x average, good x poor, average x average, average x poor or poor x poor combining parents. Therefore information on *gca* effects of the parents need to be supplemented by that of *sca* effects and hybrid mean performance. Significant positive *sca* effects in crosses between poor x poor, average x poor, average x average combiners could be due to better complementation between favorable alleles of the involved parents.

The hybrids, SKP 6 x SKI 218 ,SKP 72 x 48-1 and SKP 49 x SKI 217 had high *per se* performance, high heterosis, positive and significant *sca* effects for yield and its one or two directly related components. In such cases these hybrids can be released after testing of stability and pedigree method will also be useful for the development of new inbred lines.

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	Number of nodes upto main raceme	Length of main raceme	Number of capsules on main raceme	Number of effective branches/ plant	Total number of branches/ plant	Seed yield/ plant	100 – seed weight	Oil content
Females	4	120.84**	3050.64**	1938.93**	32.07**	946.35**	496.34**	1.20**	5.20**	1973.76	102.19**	46.97**
Males	9	144.60**	333.17**	7908.42**	89.38**	1358.67**	6318.46**	29.53**	44.50**	29734.3**	104.17**	36.38**
Females X Males	36	36.26	192.09**	670.09**	5.46**	120.80**	732.75**	0.995**	4.31**	95955.9**	7.84**	23.28**
Error	98	5.10	30.84	19.25	1.28	11.14	27.47	0.249	0.415	1683.44	3.55	2.61
$\sigma^2 gca$		4.29	66.66	189.05	2.45	45.85	118.86	0.638	0.913	11188.08	4.24	0.817
$\sigma^2 sca$		10.38	53.75	216.95	5.59	36.55	235.09	0.25	1.30	31424.17	1.43	6.89
$\sigma^2 gca / \sigma^2 sca$		0.413	1.24	0.871	0.438	1.25	0.505	2.73	0.702	0.356	2.96	0.118

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

Parents	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	Total number of branches/ plant	Seed yield/plant	100-seed weight	Oil content
Female parents											
SKP 4	0.65*	1.40	-10.89**	0.34*	-0.81	0.02	-0.07	0.64**	18.51**	2.77**	-1.84**
SKP 6	3.15**	12.80**	11.59**	1.51**	5.04**	3.13**	-0.12	0.00	91.61**	-0.36	0.96**
SKP 49	-0.51	3.77**	0.79	0.06	1.65**	1.56**	-0.09	-0.03	24.04**	-0.77**	0.35
SKP 72	-1.48**	-3.27**	0.64	-1.12**	3.39**	2.28**	0.36**	-0.09	36.21**	0.57*	-0.64**
SKP 106	-1.81**	-14.70**	-2.12**	-0.78**	-9.27**	-6.98**	-0.06	-0.52**	-170.36**	-2.21**	1.16**
SEm.±	0.32	0.80	0.63	0.16	0.48	0.75	0.07	0.09	5.88	0.27	0.23
Male parents											
SKI 160	1.52**	1.90	11.87**	1.28**	9.29**	0.44	-1.25**	-0.89**	-23.06**	-0.03	-1.97**
SKI 217	6.92**	6.30**	38.26**	3.57**	10.05**	41.13**	-1.06**	-2.05**	293.74**	-1.53**	1.97**
SKI 218	2.59**	7.77**	35.09**	3.76**	11.50**	24.28**	-1.12**	-1.63**	274.21**	0.80*	0.81*
JI 244	-0.75	3.70**	-10.80**	-1.32**	-1.29	-2.85*	-1.68**	-2.35**	-62.19**	-0.43	0.96**
JI 258	-0.88	0.23	-24.92**	-2.88**	-13.24**	-26.79**	-0.35**	-0.34*	-186.66**	0.43	-2.08**
JI 263	-3.35**	-4.57**	-18.10**	-2.10**	-2.89**	6.06**	0.04	0.15	-117.06**	-4.03**	-0.04
48 – 1	-2.01**	-2.50**	-2.04*	-0.29	-5.07**	-16.59**	-0.21	1.02**	54.87**	4.87**	1.83**
DCS 9	-3.61**	-4.43**	-28.80**	-3.05**	-15.68**	-19.6**	2.11**	1.95**	-122.73**	-2.91**	-2.14**
DCS 47	0.05	-3.70**	-2.54**	1.14**	6.09**	2.84*	1.58**	2.17**	-46.73**	-0.41	0.37
RG 737	-0.48	-4.70**	1.97*	-0.12	1.24	-8.91**	1.95**	1.97**	-64.39**	3.25**	0.28
SEm±	0.49	1.19	0.94	0.24	0.72	1.31	0.11	0.14	8.81	0.40	0.35S

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

Table 3 The best three crosses on the basis of *per se* performance, heterosis and crosses with significant *sca* effects of hybrids for eleven characters in castor

Character	Hybrid-1			Hybrid-2			Hybrid-3		
	$\bar{X}$	Heterosis	*sca*	$\bar{X}$	Heterosis	*sca*	$\bar{X}$	Heterosis	*sca*
Days to flowering		SKP 72 x DCS 9			SKP 72 x JI 263			SKP 106 x 48-1	
	51.00	-21.13**	-1.05	51.00	-19.05**	-1.32	51.67	-14.13**	-1.65
Days to maturity		SKP 72 x DCS 47			SKP 72 x JI 258			SKP 106 x 48-1	
	92.00	-22.80**	-15.07**	92.00	5.77	14.33**	94.33	-20.95**	-2.50
Plant height		SKP 106 x DCS 9			SKP 72 x DCS 9			SKP 4 x JI 244	
	34.48	0.64	-4.82*	35.47	-9.84	-6.60**	35.54	-55.22**	-12.99**
No. of nodes/plant		SKP 72 x JI 258			SKP 106 x JI 258			SKP 6 x DCS 9	
	12.72	-20.69**	-0.42	12.78	-13.97**	-0.69	12.8	-25.98**	-2.80**
Length of main raceme		SKP 72 x SKI 160			SKP 49 x SKI 217			SKP 49 x SKI 218	
	85.28	10.40**	15.18**	75.63	32.54**	6.59**	75.28	17.60**	4.71**
No. of capsules/plant		SKP 4 x SKI 217			SKP 49 x SKI 217			SKP 6 x SKI 217	
	121.93	36.59**	12.72**	119.27	24.89**	8.51**	110.5	27.93**	-1.79
No. of effective branches/plant		SKP 4 x DCS 9			SKP 72 x DCS 47			SKP 49 x DCS 9	
	8.73	54.12**	0.68**	8.67	62.50**	0.72**	8.60	30.96**	0.56**
Total No. of branches/plant		SKP 72 x DCS 47			SKP 6 x RG 737			SKP 72 x RG 737	
	13.67	81.02**	1.71**	13.67	25.19**	1.57**	13.47	39.31**	1.53**
Seed yield/plant		SKP 6 x SKI 218			SKP 72 x 48-1			SKP 49 x SKI 217	
	1104.30	65.73**	172.30**	1082.30	186.46**	424.99**	1050.00	45.87**	185.96
100-seed weight		SKP 4 x RG 737			SKP 4 x 48-1			SKP 72 x 48-1	
	41.64	10.63**	3.39**	39.54	-0.26	-0.34	38.12	11.93**	0.44
Oil content		SKP 106 x RG 737			SKP 106 x JI 244			SKP 106 x 48-1	
	53.22	20.35**	3.92**	53.20	13.83**	3.12**	52.46	15.72**	1.61**

** = Significant at P=0.01 level

The present study revealed the significance of both additive and non-additive effects in the parent material. Initial selection of parents could be done on the basis of per se performance and gca effects then biparental mating with the reciprocal recurrent selection should be employed so that additive and non- additive gene actions could be exploited for further improvement of the traits in the population.

For further work high yielding crosses like SKP 6 x SKI 218 and SKP 72 x 48-1 may be tested for their stability over years. For the development of high yielding varieties/ progenies of crosses whose parents have high gca effects (SKI 217, SKI 218, DCS 9, SKP 6 and SKP 72) may be advanced and selection can be exercised.

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Character association and path analysis for seed yield in sunflower, *Helianthus annuus* L.

E. Ravi, M. Bharathi, A. Vishnuvardhan Reddy* and M. Ganesh

Department of Genetics and Pl. Breeding, College of Agriculture, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, AP

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Abstract

Seed yield is a complex character governed by several contributing characters. Hence, character association was studied in the present investigation to assess the relationship among yield and its components for enhancing the usefulness of selection criterion to be followed while developing varieties. Character association analysis revealed strong positive association of seed yield with filled seeds/plant and seed set % under self-pollination, head diameter and harvest index. Path coefficient analysis revealed that filled seeds/plant, total drymatter/plant and harvest index had positive direct effect on seed yield/plant.

Key words: Sunflower, seed yield, character association, path analysis

Introduction

The cultivated sunflower, *Helianthus annuus* L. has emerged as one of the major edible vegetable oilseeds crop in the world, ranking second in importance after soybean. The estimation of genetic correlation coefficient between yield and its component characters has been of immense help for the indirect selection of desired plant ideotype. Yield being dependent on morpho-physiological characters of the developing effective selection strategies. Path analysis divides correlation coefficients into direct and indirect effects. With this, the breeder can determine the magnitude of direct and indirect effects of different characters on seed yield. Hence, to a better insight into the cause and effect relationship between different pairs of characters, study of correlation in conjunction with path analysis is essential.

Materials and methods

A field experiment was conducted with 63 inbred lines along with two hybrids and an open pollinated variety, Morden in *rabi*, 2001 in a Randomized Block Design replicated thrice at Directorate of Oilseeds Research Farm, Hyderabad. The spacing adopted was 60 x 30 cm. Each genotype was sown in one row of 3 m length. Recommended agronomic practices were followed to raise a healthy crop. Observations were recorded on each entry on five randomly selected plants for yield and yield attributing characters *viz.*, plant height (cm), head diameter (cm), days to maturity, 100-seed weight (g), leaf area index, total drymatter/plant (g), filled seeds/plant, unfilled seeds/plant, seed yield/plant, harvest index (%), oil content (%) and seed set under self-pollination.

Genotypic and phenotypic correlation coefficients were calculated as per Johnson *etg al.* (1955). The direct and indirect contribution of various characters to yield were calculated through path coefficient analysis by Wright (1921) and Dewey and Lu (1959(. Seed set % under self-pollination was calculated by the following formula:

$$\text{Seed set \% under SP} = \frac{\text{Number of filled seeds under SP}}{\text{Total No. of seeds under SP (filled+unfilled)}} \times 100$$

Results and discussion

The phenotypic and genotypic correlations among the yield and yield component characters in sunflower are presented in table 1. However, the genotypic correlations and phenotypic correlation were on par with each other suggesting the negligible role of environment on the genotypic expression. Seed yield component characters were found to be significantly and positively associated with seed yield/plant, mainly filled seeds/plant, plant height, head diameter, 100-seed weight, total drymatter/plant, harvest index, oil content, seed set under self-pollination (Singh *et al.*, 1998; Narayana and Patel, 1998; Satyanarayana, 2000). While, contradictory to earlier reports, negative association was also noticed for number of unfilled seeds/head (Zali *et al.*, 1977) with seed yield/plant. The character association of number of unfilled seeds with days to maturity, head diameter and filled seeds/capitulum was also found to be negative and significant. However, total drymatter/plant recorded significant and positive association with number of unfilled seeds/.plant.

* Senior Scientist (Plant Breeding), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP.

The study of inter-character association between the yield component characters revealed significant and positive association of plant height with head diameter, days to maturity, 100-seed weight, leaf area index, total drymatter/plant. Head diameter was positively associated with days to maturity, total drymatter/plant, filled seeds/plant, harvest index and seed set % under self-pollination. Regarding days to maturity, it was positively associated with 100 seed weight and seed set % under open pollination. Test weight has positive association with total drymatter/plant and oil per cent. Leaf area index also has positive association with total drymatter/plant. Total drymatter had positive association with unfilled seeds/plant. Filled seeds/plant was also positively associated with harvest index and per cent of seed set under self-pollination (Tecklewold *et al.*, 2000). Autogamy has positive association with most of the yield contributing characters except unfilled seeds/plant.

Direct and indirect effects of the path matrix for seed yield/plant showed, number of filled seeds/plant exerted maximum direct effect followed by total drymatter/plant and harvest index (Table 2) (Kathuria *et al.*, 1996). Hence, selection based on these traits would be effective in increasing yield. Test weight, plant height and head diameter also recorded positive direct effects on seed yield/plant, however, these effects are low. In contrast, unfilled seeds/plant and have recorded high negative direct effect on seed yield/plant. Days to maturity, leaf area index and oil content also recorded negative direct effect on seed yield/plant. However, these effects are low.

Table 1 The estimation of correlation coefficients (P&G) between yield and yield contributing characters in sunflower

Character		Plant height (cm)	Head diameter (cm)	100-seed weight (g)	Total drymatter/ plant (g)	Filled seeds/plant	Unfilled seeds/plant	Harvest index (%)	Seed set (%)	Seed yield/plant (g)
Plant height (cm)	P	1.0000	0.3919**	0.2634*	0.3422*	0.1998	0.0984	0.0649	0.1239	0.3768**
	G	1.0000	0.4023**	0.2794*	0.3519**	0.2089	0.1282	0.0653	0.1267	0.3849**
Head diameter (cm)	P		1.0000	0.1095	0.2543*	0.5759**	-0.1491	0.3618**	0.4643**	0.5979**
	G		1.0000	0.1153	0.2594*	0.6021**	-0.2529*	0.3767**	0.5437**	0.6125**
100-seed weight (g)	P			1.0000	0.3981**	-0.0466	-0.0618	0.1528	0.1070	0.4564**
	G			1.0000	0.4111**	-0.0550	-0.1389	0.1584	-0.0055	0.4720**
Total drymatter/plant (g)	P				1.0000	0.2070	0.1600	-0.3792**	0.1507	0.4471**
	G				1.0000	0.2159	0.2467*	-0.3754**	0.0761	0.4536**
Filled seeds/plant	P					1.0000	-0.2197	0.6309**	0.6587**	0.8128**
	G					1.0000	-0.3016*	0.6384**	0.7077**	0.8256**
Unfilled seeds/plant	P						1.0000	-0.2283	-0.4593**	-0.1519
	G						1.0000	-0.3571**	-0.7785**	-0.2487**
Harvest index (%)	P							1.0000	0.4679**	0.6030**
	G							1.0000	0.4761**	0.6029**
Seed set (%)	P								1.0000	0.5393**
	G								1.0000	0.5542**

*, ** Significant at 5 and 1% level; P = Phenotypic correlation coefficient; G = Genotypic correlation coefficient

***Table 2* Path analysis for seed yield/plant (Phenotypic and genotypic path coefficients)**

Character		Plant height (cm)	Head diameter (cm)	100-seed weight (g)	Total drymatter/ plant (g)	Filled seeds/ plant	Unfilled seeds/ plant	Harvest index (%)	Seed set (%)
Plant height (cm)	P	0.0422	0.0166	0.0111	0.0145	0.0084	0.0042	0.0027	0.0052
	G	0.1070	0.0431	0.0299	0.0377	0.0224	0.0137	0.0070	0.0136
Head diameter (cm)	P	0.0241	0.0616	0.0067	0.0157	0.0355	-0.0092	0.0233	0.0286
	G	0.0165	0.0411	0.0047	0.0107	0.0248	-0.0104	0.0155	0.0224
100-seed weight (g)	P	0.0658	0.0273	0.2497	0.0994	-0.0116	-0.0154	0.0382	0.0267
	G	0.0088	0.0036	0.0314	0.0129	-0.0017	-0.0044	0.0050	-0.0002
Total drymatter/plant (g)	P	0.1374	0.1021	0.1599	0.4015	0.0831	.0642	-0.1523	0.0605
	G	0.2334	0.1721	0.2727	0.6632	0.1432	0.1636	-0.2490	0.0505
Filled seeds/plant	P	0.1022	0.2945	-0.0238	0.1059	0.5114	-0.1124	0.3226	0.3368
	G	0.0971	0.2798	-0.0255	.0.1003	0.4647	-0.1401	0.2967	0.3289
Unfilled seeds/plant	P	-0.0050	0.0076	0.0032	-0.0082	0.0112	-0.0510	0.0116	0.0234
	G	-0.0557	0.1098	0.0603	-0.1072	0.1310	-0.4344	0.1551	0.3382
Harvest index (%)	P	0.0275	0.1532	0.0647	-0.1606	0.2671	-0.0967	0.4234	0.1981
	G	0.0395	0.2278	0.0958	-0.2269	0.3859	-0.2159	0.6045	0.2878
Seed set (%)	P	-0.0174	-0.0651	-0.0150	-0.0211	-0.0923	0.0644	-0.0656	-0.1401
	G	-0.0617	-0.2647	0.0027	-0.0371	-0.3446	0.3791	-0.2319	-0.4870
Seed yield/plant (g)	P	0.3768**	0.5978**	0.4564**	0.4471**	0.8128**	-0.1519	0.6030**	0.5393**
	G	003849**	0.6125**	0.4720**	0.4536**	0.8256**	-0.2487*	0.6029**	0.5542**
Partial R^2	P	0.0159	0.0368	0.1140	0.1795	0.4156	0.0078	0.2553	-0.0756
	G	0.0412	0.0252	0.0148	0.3009	0.3836	0.1080	0.3645	-0.2699

*, ** Significant at 5 and 1% level; P = Phenotypic path coefficients; G = Genotypic path coefficients
Phenotypic residual effect = 0.2251; Genotypic residual effect = 0.1778

The results of path analysis on the whole revealed that selection for high number of filled seeds/capitulum, moderate capitulum diameter, more test weight, medium plant height with more leaf area and high total drymatter/plant would be effective for improving the seed yield in sunflower.

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Identification of fertility restorers for new CMS sources in sunflower, *Helianthus annuus* L.

K. Rukminidevi, M. Ganesh and A.R.G. Ranganadha[1]

National Seed Project, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, AP

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Abstract

The development of commercial sunflower hybrids based on new CMS (cytoplasmic male sterile)sources is of special interest for reducing the potential risk of vulnerability to pathogens and for increasing genetic diversity. From 500 crosses involving five diverse CMS lines (four sources i.e., CMS PEF, CMS 1, PET 2 and PET 1) and 100 diverse inbreds were studied to identify fertility restorers for each CMS source in sunflower. Out of 100 inbreds tested in the cytoplasmic background of PET-2-7-1A (PET-2), 11 inbreds proved to be effective restorers, five inbreds showed segregation and 84 inbreds proved to be effective restorers. Nine inbreds behaved as restorers for ARM 245A (PET 1) and 91 were found as maintainers, six inbreds were effective restorers, nine inbreds exhibited segregation and rest of 85 inbreds were non-restorers for PFMS 274 A (PEF). The inbred ARM 247 alone could be able to restore fertility for IMS R 265 A (CMS 1) cytoplasmic source. The inbred VND-5 restored fertility in both CMS PEF and PET-1 sources. Similarly, GP-9-201-1 inbred restored fertility in CMS PEF and PET 2.

Key words: Sunflower, maintainer-restorer, CMS source

Introduction

The discovery of cytoplasmic male sterility in sunflower (*Helianthus annuus* L.) by Leclercq (1969) and subsequent identification of genes for fertility restoration by Kinman (1970) have resulted in the development of hybrids for commercial cultivation using this system. Sunflower breeders have extensively exploited the heterosis on the *Helianthus petiolaris* (PET-1) source of male sterility by utilizing few fertility restorers. Such type of dependency on a single source of male sterility could lead to narrow genetic base leading to a potential risk and high degree of genetic vulnerability in hybrid sunflower cultivation which can predispose the crop for some unforeseen situations of biotic and abiotic stresses in future years. Hence, diversification of CMS sources is inevitable in heterosis breeding which will add flexibility and nuclear diversity to breeding programmes. In order to diversify the cytoplasmic base, attempts were made and few new cytoplasmic male sterile sources have been identified. Nevertheless, using these diverse CMS sources, hybrids could not be developed because of non-availability of effective restorers. In view of the limitation, an attempt was made to identify restorers for the newly developed CMS sources.

Materials and methods

Five diverse CMS lines (four sources) *viz.*, PFMS 274 A from *H. petiolaris* SSP fallax (PEF), IMS R 265A from *H. lenticularis* (CMS I), PET-2-89A and PET-2-7-1A (PET 2) and ARM 245A (PET 1) and hundred diverse inbreds developed through population improvement programme which includes new inbreds, maintainers, restorers of PET 1 cytoplasm, Morden based inbreds and inbreds developed from Armaviriski population were used in the present studies. Each of these 100 inbreds were crossed to all five CMS lines during *kharif*, 2000 and the resulting 500 F_1s were tested during *rabi*, 2000 and *kharif*, 2001 at Experimental Farm, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad.

Each F_1 was grown in two rows of 4 m length with a spacing of 60 cm between rows and 30 cm between plants. At anthesis stage, plants were classified as male fertile/male sterile based on anther dehiscence and pollen shedding. Pollen fertility was also confirmed in the laboratory using 1% Acetocaramine staining.

Results and discussion

In general, most of the inbreds tested behaved as maintainer for all the four new CMS sources. Results indicated that out of 100 inbred lines tested in the cytoplasmic background of PET-2-7-A (i.e., PET 2), 11 inbreds *viz.*, GP-9-30-1, GP-9-220-1, GP-9-884-4, GP-9-73-5, GP-9-556-7, GP-9-811-4, GP-9-201-1, GP-1446, R-HR-R-2, ARM-239 and DRM-71-2 proved to be effective restorers. Five inbreds showed segregation and 84 inbreds exhibited male sterile reaction. Nine inbreds

[1] Senior Scientist, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP.

(GP9-1932, GP-9-856-33, GP-9-220-1, GP-9-755-1, GP-9-811-5, LIB-02-M3, VND-5 (NB), 400 B and DRM-29-II) behaved as restorers for ARM 245A (PET-1) and 91 inbreds showed maintainer reaction. In the present study, majority of the inbreds which showed fertility reaction with diverse CMS sources were obtained from recurrently selected gene pools of broad genetic base population. It is interesting to note that certain entries of Morden base could be able to restore 100% fertility with PET-2 (PET-2-7-1A x DRM-71-2 and PET-2-89A x DRM-71-2) cytoplasmic sources (Table 1).

Table 1 Per cent male fertile plants in the F_1 crosses between five CMS lines and fertility restorer lines

Cross	Number of plants			Fertile plants (%)	Remarks
	Fertile	Sterile	Total		
PFMS274A x GP9-846-5	12	8	20	60	S
PFMS274A x GP9-53-2	15	-	15	100	R
PFMS274A x GP9-58-4	15	-	15	100	R
PFMS274A x GP9-488-1	6	4	10	60	S
PFMS274A x GP9-152-7	13	2	15	86.7	S
PFMS274A x GP9-8C-2	20	-	20	100	R
PFMS274A x GP9-45B-4	8	7	15	53.3	S
PFMS274A x GP9-201-1	15	-	15	100	R
PFMS274A x GP9-58-5	20	-	20	100	R
PFMS274A x GP9-VND-5(NB)	15	-	15	100	R
PFMS274A x DRM-10-2	3	5	8	37.5	S
PFMS274A x DRM-24-1	4	9	13	30.8	S
PFMS274A x DRM-65-4	5	5	10	50	S
PFMS274A x DRM-72-2	6	5	11	54.6	S
PFMS274A x GP9-DRM-29-II	10	9	19	52.6	S
IMSR265A x ARM 247	10	-	10	100	R
IMSR265A x GP9-846-5	2	8	10	20	S
IMSR265A x GP9-709-4	2	8	10	20	S
IMSR265A x GP9-53-2	8	6	15	53.3	S
IMSR265A x GP9-871-1	6	2	8	75	S
IMSR265A x GP-1478	4	6	10	40	S
PET2-89A x ARM239	15	-	15	100	R
PET2-89A x GP9-846-5	6	4	10	60	S
PET2-89A x GP9-846-4	8	9	17	47.1	S
PET2-89A x GP9-521-1	3	7	10	30	S
PET2-89A x GP9-201-1	9	1	10	90	R
PET2-89A x GP-1446	5	5	10	50	S
PET2-89A x DRM-71-2	20	-	20	100	R
PET2-89A x DRM-65-4	4	6	10	40	S
PET2-89A x R-HR-R-2	15	-	15	100	R
PET2-7-1A x ARM239	15	-	15	100	R
PET2-7-1A x ARM 244	6	10	16	37.5	S
PET2-7-1A x ARM248	2	8	10	25	S
PET2-7-1A x GP9-30-1	15	-	15	100	R
PET2-7-1A x GP9-472-2	6	4	10	60	S
PET2-7-1A x GP9-220-1	15	-	15	100	R
PET2-7-1A x GP9-846-4	15	-	15	100	R
PET2-7-1A x GP9-733-5	14	-	14	100	R
PET2-7-1A x GP9-556-7	10	-	10	100	R
PET2-7-1A x GP9-811-4	10	-	10	100	R

Table 1 (Contd....)

Cross	Number of plants			Fertile plants (%)	Remarks
	Fertile	Sterile	Total		
PET2-7-1A x GP9-198-1	4	10	14	28.6	S
PET2-7-1A x GP9-201-1	15	-	15	100	R
PET2-7-1A x GP9-709-5	5	5	10	50	S
PET2-7-1A x GP-1446	8	-	8	100	R
PET2-7-1A x DRM-71-2	10	-	10	100	R
PET2-7-1A x R-HR-R-2	10	-	10	100	R
ARM245A x GP9-1932	15	-	15	100	R
ARM245A x GP9-856-3	16	-	16	100	R
ARM245A x GP9-220-1	15	-	15	100	R
ARM245A x GP9-755-1	10	-	10	100	R
ARM245A x GP9-811-5	9	1	10	90	R
ARM245A x LIB-02-M3	10	-	10	100	R
ARM245A x VND-5(NB)	15	-	15	100	R
ARM245A x 400B	10	-	10	100	R
ARM245A x R-83-R6	12	-	12	100	R

M : Maintainer; R : Restorer; S : Segregation

It is evident from the present investigation that various inbred lines behaved differently in four CMS backgrounds in respect of their maintainer or restorer behaviour thereby indicating that these four CMS sources are different from one another and possesses distinct mechanism of male sterility and none of the inbreds under present study was identified to restore fertility on all four diverse CMS sources. The restorers for one CMS source behaved as maintainer for other source and vice-versa. Hence, these sources can be safely included in the breeding programmes to broaden the genetic base of CMS in sunflower. Similar results of difference in fertility restoring genes for different CMS background have been reported by Frank (1979), Whelan (1980) and Virupakshappa *et al.* (1991). The promising inbreds identified as maintainers for the diverse CMS source, i.e., CMS PEF, CMS I, PET 2 and PET1 after testing their combining ability and agronomic performance will be converted as new cytoplasmic male sterile lines and may be used in sunflower improvement programmes for developing diverse hybrids with better heterosis and resistant to disease and insect pests.

In most of the hybrids with diverse CMS backgrounds segregation for fertile/sterile plants (more than 50%) was observed. These inbreds can be utilized by selfing and crossing with CMS line, so that the possibility of developing a new restorers is explored. For heterosis breeding identification of effective restorer is a basic step and it is a continuous process.

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Genetic divergence studies in sunflower, *Helianthus annuus* L. germplasm lines

B. Srinivas, Kuldeep Singh Dangi, Laxmi Prayaga* and S. Sudheer Kumar

Dept. of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad-500 030, AP

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Abstract

Genetic divergence of 45 sunflower genotypes consisting of GMU (Germplasm Monitoring Unit) lines and two controls was assessed using Mahalanobis D^2 statistic. The genotypes were grouped into 9 clusters. Days to maturity, 100-seed weight, leaf area index and total dry matter contributed maximum towards total genetic divergence. Based on mean performance, genetic distance and clustering pattern, hybridization involving parents GMU-104, GMU-118 and GMU-107 in cluster I, GMU - 109, GMU - 114, GMU - 113 and GMU - 132 in cluster IX, GMU - 122 in cluster III and Morden in cluster VI could give higher yielding hybrids.

Key words : Sunflower, genetic divergence

Introduction

Sunflower has emerged as a potential oilseed crop in Indian agriculture. Owing to its photo insensitive nature it can be cultivated throughout the year. Cultivation of sunflower is mainly for extraction of oil which ranges from 46-52 per cent. Selection of parents based on their genetic divergence is a pre-requisite in a hybrid breeding programme. Asthana and Pandey (1980) reported that the geographic diversity may not necessarily be related with genetic diversity. Parental diversity is essential to obtain superior genotypes in later generation. For estimation of degree of genetic divergence in germplasm collection of various crops multivariate analysis using D^2 statistic has been found to be a potential biometrical tool (Rao, 1952; Singh and Gupta, 1968). The utility of multivariate analysis and use of generalized distance (D^2) as a quantitative measure of genetic divergence was illustrated in crop plants and other biological populations. In this context, an attempt was made to study the genetic diversity in germplasm monitoring unit (GMU) lines of sunflower crop.

Materials and methods

The material for the present study comprised of 45 genotypes, including 'Morden' and KBSH-1 as checks, was evaluated in Randomized Block Design with two replications at College Farm, College of Agriculture, Rajendranagar, Hyderabad during summer, 2004. Data were recorded on various morphophysiological, seed yield and its component traits *viz.*, days to 50% flowering days to maturity, plant height, stem diameter, head diameter, head weight, number of unfilled seeds per head number of filled seeds per head, total number of seeds/head, seed filling per cent, 100 seed weight, seed yield/plant, leaf area index, total dry matter/plant harvest index. Genetic diversity was studied by analyzing the data using Mahalanobis (1936) D^2 statistic as described by Rao (1952). The genotypes were grouped into different clusters according to Toucher's method (Rao, 1952) and inter and intra cluster distances were calculated as per Singh and Chaudhary (1977).

Results and discussion

Forty five 45 genotypes were grouped into 9 clusters of which cluster II was the largest comprising of 12 genotypes followed by cluster VIII with 11 genotypes, cluster IV and V each containing 5 genotypes, cluster IX with 4 genotypes, cluster I and VII with 3 genotypes each and clusters III and VI each with 1 genotype only (Table 1).

Table 1 Distribution of genotypes of sunflower in different clusters

Cluster No.	No. of Genotypes	Genotypes
I	3	GMU-104, 118, 107
II	12	GMU-106, 145, 133, 115, 117, 157, 149, 137, 130, 131, 101, 102
III	1	GMU-122
IV	5	GMU-108, 136, 134, 140, 192
V	5	GMU-121, 138, 142, KBSH-1, **GMU-196**
VI	1	Morden
VII	3	GMU-120, 141, 103
VIII	11	GMU-128, 162, 129, 185, 176, 135, 158, 177, 181, 175, 110
IX	4	GMU-109, 114, 113, 132

The intra cluster D^2 values ranged from zero (cluster III and VI) to 20.021 (cluster VII). From the inter cluster D values

* Senior Scientist (SS) (Plant Physiology), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP.

for nine clusters, it can be seen that the highest divergence occurred between cluster I and IX (48.501) followed by cluster III and VI (42.9), cluster I and III (40.184) and cluster I and VI (39.379) indicating the presence of greater diversity between genotypes of these groups (Table 2). Hence, crossing between genotypes belonging to these clusters may result in high heterosis, which could be exploited in crop improvement. The least inter cluster distance was noticed between cluster IV and VIII (15.327) followed by cluster IV and V (16.182) and cluster V and VIII (16.310) indicating the close relationship and similarity for most of the traits of the genotypes in these clusters. The cluster means exhibited that minimum and maximum values, respectively, were plant height (cluster VI) and (cluster II), number of filled seeds (cluster IX) and (cluster VI), 100 seed weight (cluster III) and (cluster VII) , seed yield (cluster III) and (cluster VII), leaf area index (cluster III) and (cluster V) respectively (Table 3).

Table 2 Average intra (diagonal) and inter cluster D^2 and D values of 45 genotypes of sunflower

	1 Cluster	2 Cluster	3 Cluster	4 Cluster	5 Cluster	6 Cluster	7 Cluster	8 Cluster	9 Cluster
Cluster I	**284.879 (16.878)**	600.009 (24.495)	1614.772 (40.184)	481.174 (21.935)	814.098 (28.532)	1550.718 (39.379)	894.203 (29.903)	694.836 (26.359)	2352.409 (48.501)
Cluster II		**208.47 (14.438)**	516.109 (22.718)	447.792 (21.161)	536.122 (23.154)	1360.947 (36.891)	569.191 (23.857)	314.060 (17.721)	1264.250 (35.556)
Cluster III			**0.00**	999.737 (31.618)	894.647 (29.910)	1840.425 (42.900)	1120.948 (33.460)	630.828 (25.116)	888.357 (29.805)
Cluster IV				**104.514 (10.223)**	261.866 (16.182)	560.218 (23.668)	562.932 (23.726)	234.922 (15.327)	1064.958 (32.633)
Cluster V					**181.978 (13.489)**	500.172 (22.364)	600.016 (24.495)	266.019 (16.310)	679.122 (26.059)
Cluster VI						**0.00**	835.500 (28.905)	653.766 (25.568)	723.676 (26.901)
Cluster VII							**441.921 (21.021)**	365.889 (19.128)	1151.419 (33.932)
Cluster VIII								**130.216 (11.411)**	754.968 (27.476)
Cluster IX									**217.672 (14.753)**

Figures in parenthesis indicate D values.

Table 3 Mean of cluster from 45 genotypes of sunflower for 15 traits

	Days to 50% flowering	Days to maturity	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Head weight (g)	No. of unfilled seeds/head	No. of filled seeds/ head	Total No. of seeds/ head	Seed filling (%)	100-seed weight (g)	Seed yield/ plant (g)	Leaf area index	Total dry matter/ plant (g)	Harvest index (%)
Cluster I	58.00	82.33	135.15	2.19	13.33	40.60	122.71	597.74	720.45	83.00	3.83	23.11	2.37	97.07	24.47
Cluster II	60.00	90.12	146.46	2.17	13.64	44.67	93.39	535.62	629.00	84.95	4.35	23.15	2.40	103.92	22.18
Cluster III	57.50	92.50	133.33	2.01	10.15	29.43	96.00	44.10	540.10	82.17	3.56	16.30	1.41	81.25	20.07
Cluster IV	55.80	84.50	112.17	1.71	12.93	40.97	117.73	484.36	502.08	79.70	3.81	18.31	1.95	95.78	19.01
Cluster V	53.70	84.60	119.40	1.86	12.60	36.92	104.58	477.83	582.42	80.57	4.24	21.51	2.69	90.06	22.70
Cluster VI	52.50	84.50	100.35	1.78	14.95	52.90	149.82	677.43	827.26	81.89	5.17	35.67	2.08	122.81	29.04
Cluster VII	57.83	88.17	145.85	2.08	15.74	47.58	112.44	624.51	736.96	84.02	6.28	38.47	2.42	123.44	31.27
Cluster VIII	54.54	85.54	130.02	1.94	13.14	44.07	100.50	485.97	586.47	82.28	4.92	23.62	2.02	103.27	23.05
Cluster IX	52.12	89.87	114.63	1.60	12.76	42.72	129.83	415.46	545.29	76.30	5.08	21.15	2.30	93.51	23.14

The per cent contribution of the characters studied towards genetic divergence showed that the trait days to maturity contributed maximum (36.8%) followed by 100 seed weight (16.7%), leaf area index (16.3%) and total dry matter (9.4%). These results were in accordance with the findings of Sridhar (1999) and Subrahmanyam *et al.* (2003). In the present study based on inter cluster distances the genotypes from the clusters I and IX, III and VI, I and III and I and VI could be selected for hybridization programme in achieving the novel recombinants.

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Response of groundnut, *Arachis hypogaea* to sulphur, boron and FYM doses in an Ultic Hapludalf of Meghalaya

M.S. Venkatesh, B. Majumdar, Kailash Kumar and Patiram

Division of Soil Science, ICAR Research Complex for NEH Region, Umroi Road, Umiam-793 103, Meghalaya

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Abstract

Field experiments were conducted during the *kharif* seasons of 2000, 2001 and 2002 to study the response of groundnut (*Arachis hypogaea*) to sulphur, boron and FYM levels. S application @ 40 kg/ha resulted in maximum yield, quality and residual soil nutrient status. B application @ 3 kg/ha was beneficial for getting maximum pod yield, protein content, S and B uptake and residual nutrient status. FYM @ 5t/ha significantly increased the yield and quality of groundnut. Interaction of S and B levels were significant for S and B uptake by kernels and soil available S status whereas interaction of SxFYM was significant for S and B uptake. B uptake and soil available B were also significantly and positively influenced by BxFYM interaction.

Key words: Sulphur, boron, FYM, groundnut, Ultic Hapludalf, Meghalaya

Introduction

Almost all the soils of Meghalaya are acidic in nature and soil acidity is one of the most important factors responsible for low crop productivity. Acid soils not only suffer from the deficiency of primary nutrient elements but also secondary and micronutrients particularly S, Zn, B and Mo (Verma and Bhatt, 2001). Groundnut is emerging as an important oilseed crop of Meghalaya and fits well in the cropping systems in uplands. S and B are both known to play important role in oil and protein synthesis. Farm Yard Manure (FYM) is used in acid soils as a source of major and micronutrients which also acts as an amendment to Al-toxicity. Response of crops to S and B levels in acid soils of Meghalaya has been observed individually (Dwivedi *et al.*, 1993; Venkatesh *et al.*, 2002). However, the information on the combined influence of these nutrients along with FYM on yield and quality is very limited for groundnut. Present investigation was therefore conducted to study the combined influence of S, B and FYM levels on yield, quality and residual nutrient status in groundnut in an acidic Alfisol of Meghalaya.

Materials and methods

Field experiments were conducted during the *kharif* seasons of 2000, 2001 and 2002 at ICAR Research Complex for NEH Region, Umiam, Meghalaya to study the response of groundnut (cv. ICGS- 76) to different levels of S (0, 20 and 40 kg/ha through gypsum), B (0, 1.5 and 3.0 kg/ha through borax) and FYM (0 and 5t/ha). FYM contained 0.18 % S and 20 ppm boron on dry weight basis. The experimental soil was Ultic Hapludalf, sandy loam in texture, with pH 4.80, organic carbon 1.56%, available S and B contents 12.5 and 0.4 kg/ha, respectively. Experiment was laid out in three factorial RBD with 3 replications. Groundnut was sown in the first week of June and a common basal dose of N, P and K @ 20, 26 and 30 kg/ha was applied in furrows at the time of sowing. The crop was raised under normal agronomic practices. The pod yield and other quality parameters were estimated from the samples drawn after harvest. Shelling per cent was calculated as (kernel weight/Pod weight) x 100. Kernel samples were dried in hot air oven at 70°C, powdered and digested in di acid mixture (HNO_3 : $HClO_4$ :: 10 : 4) and analysed for S and B contents. Oil content in the kernels was determined by extracting with petroleum ether using Soxhlet apparatus (AOAC, 1970). N content in the kernels was analysed by micro-Kjeldahl method using semi-automatic N analyser and protein content was calculated by multiplying the total N by 6.25. Yield parameters, quality and nutrient uptake data are reported as pooled mean of 3 years. Soil samples were collected after the harvest of 3rd year crop and analysed for pH (1:2 soil : water suspension), organic carbon (wet oxidation method), available S (0.15% $CaCl_2$ extractable, by turbidimetric method) and available B [hot $Ca(OH)_2$ extractable, by Azo-methine - H method] as outlined by Page *et al.* (1982).

Results and discussion

Yield parameters: Pod yield of groundnut increased significantly by the application of all the levels of S, B and FYM (Table 1). An increase of 14.7, 21.5 and 7.0 % in pod yield was recorded with the application of 40 kg S, 3 kg B and 5t FYM /ha, respectively. The interaction effect of B x S x FYM was not significant for pod yield but the highest pod yield was recorded in S40 + B3 + FYM5 treatment (3220 kg/ha). These treatments showed almost similar effect on the shelling per cent and 100 kernel weight, indicate that groundnut crop responded to S, B and FYM applications since soil was low in available S and B

contents. Venkatesh *et al.* (2002) and Dwivedi *et al.* (1993) observed significant response of groundnut to S levels and pea to B levels in acid soil of Meghalaya, respectively.

Protein and oil contents: All the levels of S, B and FYM significantly increased the oil and protein contents (Table 1). Maximum oil and protein content was observed in S_{40} + B_3 + FYM_5 treatment. S fertilisation might have resulted in stepped up synthesis of S containing amino acids in groundnut which are the building blocks of proteins (Tandon, 1991). Increase in oil content due to S application was the result of protein containing S in oil storage organs of oil seed crops (Subbaiah and Singh, 1970). Increase in oil and protein content due to B addition might be because of its involvement in flower and seed production (Tandon, 1991). Positive and significant effect of B and FYM on oil and protein content of groundnut was earlier reported by Patgiri (1995) and Patil *et al.* (1981). Interaction of S, B and FYM levels was not significant for oil and protein contents.

S and B uptake by kernels: Increasing levels of S, B and FYM resulted in significant increase in S and B uptake (Table 1). Interaction of SxB levels was significant for S and B uptake by kernels (Table 2). Highest S and B uptake were observed at S_{40} + B_3 levels. B and S application acted in a highly synergistic manner in groundnut was reported earlier by Karle and Babula, (1985). This was further confirmed by the positive and significant interaction effect of SxB on available S content of soil (Table 2). Interaction of S x FYM was also found significant for S and B uptake while B x FYM interaction was significant for B uptake only. FYM application might have contributed available forms of S and B in soil solution. Maximum S and B uptake was recorded with S_{40} FYM_5 and B_3 FYM_5 treatments, respectively (Table 2).

Soil properties: The available S and B contents increased in the post harvest soil (after 3 years of experimentation) significantly with their respective applications (Table 1). FYM application also significantly increased the availability of S and B in soil. There was significant positive interaction between BxS on available S content in the soil (Table 2). Both the levels of S increased the available S content at each level of B. However, the effect of B on available S was significant only at the highest level of 40 kg S/ha. The highest available S content was recorded at S_{40} B_3 treatment (21.9 kg/ha). Interaction of BxFYM was significant for B uptake by the kernels and available B content of soil. There was 87-99 and 63-68% increase in B uptake and available B content respectively by FYM application at various levels of B application. This might be due to the large portion of water soluble B extracted from soil organic matter (Martens, 1968). Interaction of SxFYM was positively significant for the uptake of both B and S uptake by kernels. FYM application increased the B and S uptake significantly at all the S levels. This also showed the contribution of B and S from FYM. Soil pH was found to decrease with addition of S and FYM which might be because of gypsum used as source of sulphur, whereas soil pH was unaffected by B.

It could be inferred from the above study that sulphur, boron and FYM applications @ 40 kg S, 3 kg B and 5t FYM /ha significantly increased the yield and quality of groundnut and found optimum in Ultic Hapludalf of Meghalaya.

Table 1 Effect of S, B and FYM levels on pod yield, yield parameters, quality, nutrient uptake by groundnut and soil properties

Treatment	Pod yield (kg/ha)	Shelling (%)	100 kernel weight (g)	Oil content (%)	Protein content (%)	S uptake by kernels (kg/ha)	B uptake by kernels (g/ha)	Soil pH	Organic C (%)	Available S (kg/ha)	Available B (kg/ha)
S level (kg/ha)											
0	2440	67.1	59.3	46.3	21.4	2.3	16.0	4.8	1.7	13.6	0.5
20	2635	69.0	61.6	47.5	23.1	3.2	17.8	4.7	1.8	17.0	0.5
40	2800	70.5	63.0	48.7	25.2	5.1	23.0	4.6	1.9	19.0	0.6
CD (P=0.05)	151	1.0	1.0	0.1	0.3	0.2	1.2	0.1	0.1	0.9	0.1
B levels (kg/ha)											
0	2394	67.3	60.1	47.2	22.7	2.9	11.4	4.7	1.7	15.5	0.4
1.5	2573	69.1	61.5	47.6	23.2	3.5	18.5	4.8	1.8	16.4	0.5
3.0	2908	70.1	62.3	47.7	23.7	4.3	27.0	4.7	1.8	17.6	0.7
CD(P=0.05)	151	1.0	1.0	0.1	0.3	0.2	1.2	0.1	0.1	0.9	0.1
FYM levels (t/ha)											
0	2536	68.2	60.1	47.4	23.1	3.3	16.6	4.8	1.7	16.1	0.5
5	2714	69.5	62.4	47.6	23.4	3.8	21.4	4.6	1.8	16.9	0.6
CD (P=0.05)	123	0.8	0.8	0.1	0.2	0.2	1.0	0.1	0.1	0.8	0.1

Table 2 Interaction effects of S, B and FYM levels on S and B uptake by groundnut and soil available B and S contents

S level (kg/ha)	B level (kg/ha)			
	0	1.5	3.0	Mean
	(A) S uptake (kg/ha)			
0	2.0	2.0	2.7	2.2
20	2.7	3.2	3.8	3.2
40	4.0	5.0	6.4	5.1
Mean	2.9	3.4	4.3	
CD (P=0.05)	BxS : 0.3			

B level (kg/ha)			
0	1.5	3.0	Mean
(B) B uptake (g/ha)			
8.8	15.9	23.5	16.0
12.6	16.2	24.8	17.9
12.9	23.4	32.8	23.0
11.4	18.5	27.0	
BxS : 2.1			

B level (kg/ha)			
0	1.5	3.0	Mean
© Available S (kg/ha)			
13.5	13.5	13.7	13.6
16.2	17.4	17.4	17.0
17.0	18.3	21.9	19.0
15.5	16.4	17.6	
BxS : 1.6			

	S level (kg/ha)			
	0	20	40	Mean
	(D) S uptake (kg/ha)			
0	2.2	2.5	3.0	2.5
5	3.5	4.7	5.5	4.6
Mean	2.8	3.6	4.3	
CD (P=0.05)	SxFYM : 0.3			

S level (kg/ha)			
0	20	40	Mean
(E) B uptake (g/ha)			
14.6	17.5	15.6	15.9
20.1	19.5	26.5	22.1
17.4	18.5	21.0	
SxFYM:1.7			

B level (kg/ha)			
0	1.5	3.0	Mean
(F) B uptake (g/ha)			
10.5	12.4	16.2	13.0
20.8	23.1	31.0	24.9
15.6	17.7	23.6	
BxFYM : 1.7			

B level (kg/ha)			
0	1.5	3.0	Mean
(G) Available B (kg/ha)			
0.4	0.4	0.5	0.4
0.6	0.6	0.8	0.7
0.5	0.5	0.6	
BxFYM : 0.1			

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Integrated weed management in mustard, *Brassica juncea* (L.) Czern & Coss under irrigated conditions

Dileep Kachroo and B.R. Bazaya

Sher-E-Kashmir University of Agril. Sciences and Technology-J, Division of Agronomy, R.S. Pura, Jammu-181 102, J&K

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Abstract

A field experiment was conducted during the *rabi* season of 1999 and 2000 to study the effect of various weed management practices on yield, weed growth and nitrogen uptake by weeds and mustard under irrigated conditions. Among the weed control methods, minimum weed density and dry weight were recorded with fluchloralin @ 0.70 kg a.i./ha applied as pre-plant incorporation (PPI) supplemented with two hand weedings at 30 and 60 days after sowing (DAS). Weedy check till maturity reduced the seed yield by 34.19% while minimum reduction was recorded with PPI of fluchloralin @ 0.70 kg a.i./ha + 2 hand weeding at 30 and 60 DAS (8.72%) as compared to weed-free check. Weedy check till maturity removed significantly highest nitrogen through weeds (29.6 kg/ha). Pre-plant incorporation of fluchloralin supplemented with hand weeding at 30 DAS resulted in higher net income and benefit-cost ratio. Moreover, the plastic mulch treated plots gave highest seed yield, nitrogen uptake by crops and lowest weed growth than other treatments but were at with weed free check.

Key words: Weed management, mustard, weed control efficiency uptake

Introduction

Rapeseed mustard occupies a prominent place as an edible oilseed crop in India. It is grown in about 71.03 thousand ha and producing 480 thousand q of seed yield in Jammu and Kashmir (Anonymous, 2001), which indicates that it still lags behind in terms of average yield compared to national level. It is attributed mainly due to the lack of proper input management. Yield losses due to weed infestation alone amounts to 19-42% in mustard (Bhan *et al.*, 1998), which necessitates an immediate attention for its immediate control. The integrated weed management approach seems a desirable practice that not only aims at reducing the dosage of herbicides but also alleviate the residue and pollution problems besides providing the effective and acceptable means of weed control. Among the herbicides the fluchloralin and pendimethalin at 1.0 kg a.i./ha as pre-plant application were found to provide effective control of weeds as well as increased the seed yield and test weight of mustard significantly over control (Chauhan *et al.*, 1993). Moreover, the herbicide mainly Isoproturon applied as pre-emergence at 1.0 kg a.i./ha in mustard gave not only effective control of weeds but also increased the seed yield significantly than control plots (Yadav *et al.*, 1995). The research endure in this direction seems meager under the climatic condition of Jammu region. Hence, the present investigation was undertaken with the objectives to find out the weed control efficiency, its relative economics and also observe the relative density of individual weed species *vis-a-vis* to work out the pattern of nutrient removal by crops and weeds in order to increase the productivity of the mustard through effective weed management practices under the climatic conditions of Jammu.

Materials and methods

A field experiment was conducted on the Alfisols during the *rabi* seasons of 1999-2000 and 2009-01 at Research Farm, Sher-E-Kashmir University of Agricultural Sciences and Technology, J, R.S. Pura, Jammu under irrigated conditions. The soil was clay loam, with pH 6.2, organic carbon 0.73%, available N 218.54, P_2O_5 18.70 kg and K_2O 125.40 kg/ha. Twelve treatments comprising weedy check and weed free checks were evaluated (Table 1). Mustard cv. Pusa bold was sown on Oct. 25, 1999 and Oct. 27, 2000 at 5 kg/ha at 30 cm x 10 cm between rows and plants. The sowing was done by *kaira* method in all the plots except the one which were treated with plastic mulch cover, were dibbling method was used. Black polythene sheet (25 μ thickness) was used as mulch and the holes of 2.5 cm diameter were made at a distance of 30 cm between rows and 10 cm between plants. The herbicides were applied as per treatments using 600 l water/ha. Crop was fertilized with 60 kg P_2O_5 + 15 K_2O kg/ha. Full dose of P and K and half dose of N were applied as basal at the time of sowing and rest was top-dressed at the time of first irrigation (54 DAS). Observations on weed composition and dry matter were recorded from 3 random quadrates of 0.25 m^2 in each plot at harvest. Total rainfall received during the respective years was 80.9 mm and 43.5 mm. The Bartlett's t-test of homogeneity was followed wherever the pooled analysis for two years data was carried out.

Results and discussion

The major weed flora in the experimental site comprised broad leaves weeds m; *Anagallis arvensis*, *Fumaria parviflora*, *Lathyrus aphaca* L.; *Vicia sativa* L.; *Medicago denticulata*, Sedges; *Cyprus rotundus* and Grassy weeds: *Cynodon dactylon* L.; *Avena fatua* L. and *Phalaris minor*. The relative density of individual weed species in per cent of total weed density at various stages of crop growth under weedy check conditions is depicted in Fig. 1 (Table 2) Application of herbicides alone or in combination with hand weeding or under plastic mulch cover resulted in significant decrease in total number of weeds and their dry matter as compared to weedy check (Table 1). Fluchloralin applied as pre-planting and integrated with two hand weeding at 30 and 60 DAS was found most effective in controlling density and dry weight of weeds significantly than other treatments in comparison. Might be as fluchloralin being a soil active herbicide have influenced the germination of weeds initially and latter subsequent hand weeding kept the weeds below the threshold value. These results are in conformity with the Tomar and Namdeo (1991).

Table 1 Influence of various treatments on weed population, dry weight and nutrient uptake by mustard and weeds (Average of two years)

Treatment	Weed population/ m^2 at harvest	Weed dry weight (g/ha)	Weed control efficiency (%)	Weed index (%)	N-uptake (kg/ha) mustard				Total uptake (kg/ha)
					Seed	Stover	Total	Weeds	
Weedy check	250	136.5	-	34.2	24.7	10.8	35.5	29.6	65.1
Weed free check	0	0.0	100	-	40.7	23.5	64.2	0.0	64.0
Plastic mulch	0	0.0	100	-	41.3	24.1	65.4	0.0	65.4
Fluchloralin @ 0.70 kg a.i./ha	112	90.0	52	21.9	30.7	15.1	45.8	18.9	64.7
Isoproturon @ 1.0 kg a.i./ha	129	94.0	48	25.9	29.1	14.2	43.3	19.7	63.0
Pendimethalin @ 1.0 kg a.i./ha	124	91.9	50	23.6	29.9	14.8	44.7	19.1	63.8
Fluchloraljn @ 0.70 kg a.i./ha + 1 HW at 30 DAS	59	58.4	77	12.7	34.8	18.5	53.3	11.7	65.0
Fluchloraljn @ 0.70 kg a.i./ha + 2 HW at 30 and 60 DAS	36	39.8	85	8.9	36.6	19.7	56.4	7.8	64.2
Isoproturon @ 1.0 kg a.i./ha + 1 HW at 30 DAS	69	61.8	72	14.2	33.6	17.6	51.3	12.5	63.8
Isoproturon @ 1.0 kg a.i./ha + 2 HW at 30 and 60 DAS	51	45.4	80	9.5	36.3	19.2	55.5	9.2	64.7
Pendimethalin @ 1.0 kg a.i./ha + 1 HW at 30 DAS	67	60.0	73	13.9	34.5	17.9	52.4	12.2	64.6
Pendimethalin @ 1.0 kg a.i./ha + 2 HW at 30 and 60 DAS	41	42.5	84	9.2	36.5	19.8	56.3	8.5	64.8
SEm±	0.26	0.32	-	-	1.0	0.8	1.8	0.1	1.8
CD (P=0.05)	0.75	0.94	-	-	3.0	2.3	5.8	0.4	5.9

Original data subjected to square root ($\sqrt{x+0.5}$) transformation before analysis

Table 2 Relative density of individual weed species in per cent of total weed density at various stages of crop growth under weedy condition

Weed species	Days after sowing			
	30	60	90	At harvest
A) Broad leaved weeds				
Anagallis arvensis L.	19	20	21	22
Fumaria parviflora L.	14	15	15	13
Lathyrus aphaca L.	13	10	9	10
Vicia sativa L.	9	9	8	7
Medicago denticulata	27	25	25	23
B) Sedge				
Cyperus rotundus L.	5	5	6	8
C) Grassy weeds				
Cynodon dactylon L	6	5	7	10
Phalaris minor L.	7	7	6	5
Avena fatua Retz.	2	3	2	2

Highest weed control efficiency was obtained with weed free (100%) and plastic mulch covered plots (100%), followed by fluchloralin + 2 hand weedings at 30 and 60 DAS (85.48%). The highest weed control efficiency with the above treatment would be attributed due to lower weed dry weight. Madhavi *et al.* (1997) also reported the similar findings.

The maximum seed yield of mustard was obtained from plastic mulch treated plots followed by weed free check (Table 3). The plastic mulch not only suppressed the weeds but also left no toxic effect on the mustard crop, which thereby improves the seed and stover yield of mustard. Similar results have been reported by Ghosh *et al.* (1993).

Integration of fluchloralin at 0.70 kg a.i./ha supplemented with 2 hand weedings at 30 and 60 DAS resulted in maximum seed and stover yield which may be due to the fact that fluchloralin applied as pre-plant incorporation had suppressed the weed growth initially and also two hand weedings at 30 and 60 DAS had coincided with the critical crop growth stages resulted in higher yields. Higher yields with the above treatments were also be attributed to significant reduction in weed density, dry weight and improved yield attributes i.e., number of siliquae/plant, number of seeds/siliquae and test weight (g). Weedy check till maturity resulted in 34.19% reduction in seed yield, whereas 8.72% was recorded in fluchloralin 0.7 kg a.i./ha followed by 2 hand weeding at 30 and 60 DAS.

Table 3 Yield attributes, yield and economics of mustard under various weed control treatments

Treatment	Yield (kg/ha)				No. of siliqua/ plant*	No. of seeds/ siliqua	Test weight (g)*	Net income (Rs/ha)*	Benefit cost ratio*
	Seed		Stover						
	1999	2000	1999	2000					
Weedy check	1083	1106	2173	2216	113	10	5	8927	1.69
Weed free check	1630	1695	3390	3526	119	14	6	11271	1.10
Plastic mulch	1668	1701	3449	3518	201	14	5	12063	1.24
Fluchloralin @ 0.70 kg a.i./ha	1273	1324	2600	2704	142	11	5	10872	1.84
Isoproturon @ 1.0 kg a.i./ha	1220	1244	2500	2550	131	11	5	10161	1.75
Pendimethalin @ 1.0 kg a.i./ha	1245	1295	2550	2652	137	11	5	10516	1.79
Fluchloralin @ 0.70 kg a.i./ha + 1 HW at 30 DAS	1437	1466	3000	3060	167	12	5	12212	1.85
Fluchloralin @ 0.70 kg a.i./ha + 2 HW at 30 and 60 DAS	1500	1530	3100	3163	176	13	5	12332	1.69
Isoproturon @ 1.0 kg a.i./ha + 1 HW at 30 DAS	1398	1454	2880	2995	164	13	5	11907	1.83
Isoproturon @ 1.0 kg a.i./ha + 2 HW at 30 and 60 DAS	1476	1535	3042	3164	173	13	5	12228	1.68
Pendimethalin @ 1.0 kg a.i./ha + 1 HW at 30 DAS	1418	1446	2920	2978	159	12	5	11978	1.82
Pendimethalin @ 1.0 kg a.i./ha + 2 HW at 30 and 60 DAS	1481	1540	3074	3197	176	13	6	12218	1.67
SEm±	38	40	89	91	5.8	0.35	0.07	-	-
CD (P=0.05)	112	117	261	267	16.9	1.01	0.18	-	-

Cost of Fluchloralin = Rs. 510/-, Isoproturon = Rs. 420/-; Pendimethalin = Rs. 495/-; Plastic mulch for one ha = Rs. 4500/- and mustard seed = Rs. 1300/quintal during 1999-2000

*Average of two years

More N uptake by mustard crop was recorded with weed free and plastic mulch treated plots (Table 1). Among the herbicides treatments, integration of fluchloralin + 2 hand weedings 30 and 60 DAS produced highest N uptake by mustard. However, weedy check treatment depleted the highest amount of N through weeds and the lowest amount of N by the mustard crop which is mainly due to high weed infestation and poor crop yield (Table 1). The highest total

N-uptake was recorded in weed free and plastic mulch *treated plots followed by fluchloralin + 2 hand weedings.* Pre-plant incorporation of fluchloralin at 0.70 kg a.i./ha supplemented with one hand weeding at 30 DAS resulted highest net income and benefit : cost ratio. It might be due to lower expenditure of labour charges as compared to fluchloralin 0.70 kg a.i./ha along with two hand weeding. However, the higher expenditure in terms of cost of cultivation of mustard occurred in weed free check and plastic mulch treatments due to more labour charges and higher cost of plastic (polythene), respectively).

It can be concluded that under irrigated conditions of mustard weeds can be controlled effectively and economically by pre-plant incorporation of influchloralin at 0.70 kg a.i./ha coupled with one hand weeding at 30 days after sowing. However, the plastic mulch treatment produced slightly higher B:C ratio (1.23) than weed free check (1.08).

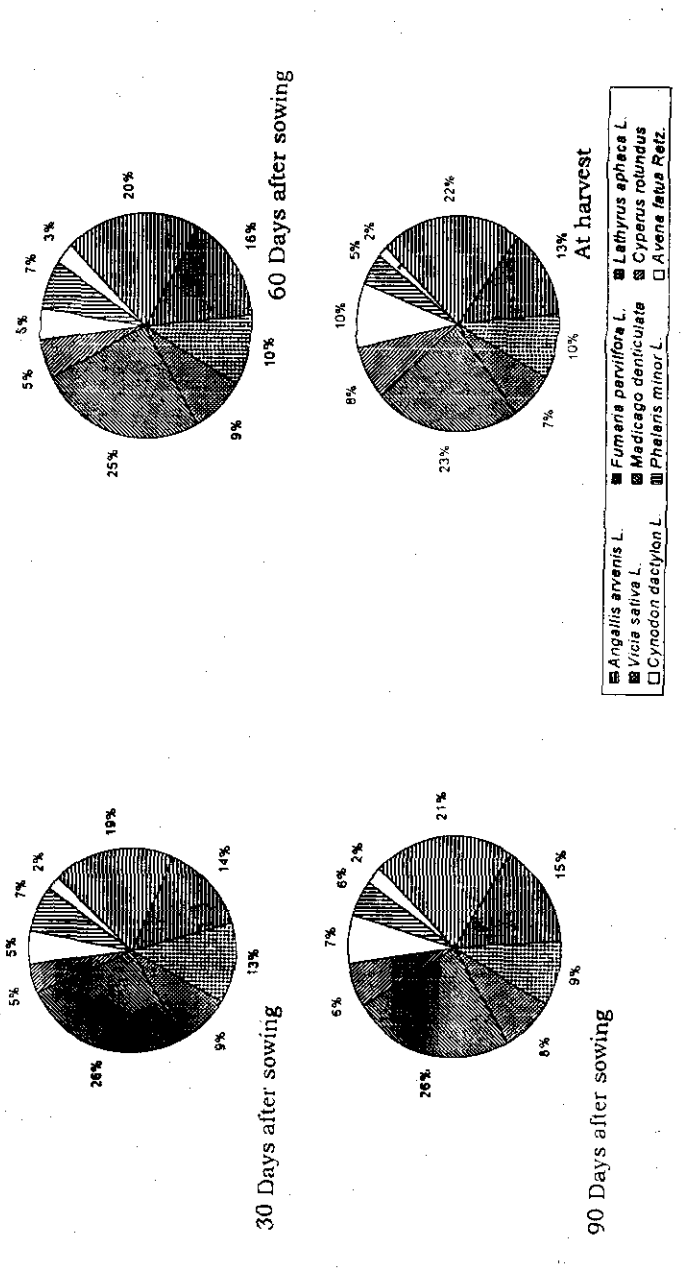

Fig. 1 Relative density of individual weed species in per cent of total weeds density at various crop growth stages under weedy condition

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Sustainable soybean - wheat cropping system through long term fertilizer application

S.D. Billore, O.P. Joshi, A. Ramesh and A.K. Vyas

National Research Centre for Soybean, Indore-452 017, Madhya Pradesh

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Abstract

A long-term experiment on soybean-wheat cropping systems under varied nutrient management situations was conducted to assess the stability and sustainability of the system. The studies revealed that application of FYM + RDF (20 : 26 : 17 NPK kg/ha) and RDF (120 : 26 : 30 NPK kg/ha) + hand weeding sustained the soybean-wheat cropping system productivity. Relative stability also indicated these treatments were relatively stable over other treatments. Therefore, regular application of FYM with recommended dose of fertilizer and hand weeding sustained the productivity of the system over years.

Keywords: Sustainable yield index, soybean-wheat system, nutrient management

Introduction

Integration of organics with inorganic fertilizers is considered as an appropriate way to sustain the productivity of sole crop or a cropping system. The component crops in a system may have different protocol of nutrient management than considered individually. This necessitates readjustments in scheduling of nutrient management for a cropping system. Conventional analysis of variance for each year is not likely to provide the overall assessment of the system stability on account of complexity of factors of prevailing environments. In the present study a long-term fertilizer experiment was utilized to work out sustainability index, stability and relative stability of different treatments in the most predominant cropping system of soybean (*Glycine max* (L.) Merril) - wheat (*Triticum aestivum* (L.) *emend.* Fiori & Paol.) in Central India.

Materials and methods

The data from a long-term field experiment initiated in *kharif*, 1993 involving soybean (cv. Ahilya 1) - wheat (cv. Mangla) crop sequence at the Research Farm, National Research Centre for Soybean, Indore and continued up to *Rabi*, 1998 was utilized to generate the information. The soil belonged to 'Sarol Series' (*fine, montmorollinitic,* iso-hyperthermic, typic chromusterts). The soil analysis revealed pH 7.86, EC 0.14 dS/m, organic carbon 0.35 %, available phosphorus 11 kg/ha and available potassium 240 kg/ha.

The experiment was conducted in Randomized Block Design with 10 treatments replicated four times. The treatments comprised of control, 50 and 150 % of recommended NPK, 100 % of recommended NPK, 100 % recommended NPK plus hand weeding, 100 % recommended NPK plus zinc @ 10 kg/ha as $ZnSO_4$ (applied to wheat only), 100 % NPK plus 10 tonnes FYM/ha, 100 % recommended N, 100 % recommended NP and 100 % recommended NPK minus sulphur. The carriers used for last treatment were di-ammonium phosphate and muriate of potash. The recommended level of NPK was 20:26:17 kg/ha for soybean and 120: 26: 33 kg/ha for wheat. The soybean was sown with the onset of monsoon (last week of June and first week of July) followed by wheat in last week of October in each year. Soybean was grown under rainfed and wheat under irrigated situations.

The yield stability was computed following simple regression coefficient and mean over the years (Finlay and Wilkinson, 1963). The relative stability of the treatments was evaluated (Raun *et al.*, 1993) and sustainable yield index was computed (Singh *et al.*, 1990).

Results and discussion

Crop yields: The results over six years indicated that the application of nutrients singly or in combination significantly improved the yield of both the crops over control (Table 1). The response to supplemented nutrients was of lower magnitude in soybean than wheat. Application of N, NP and NPK could raise the yield of soybean by 14.3, 10.3 and 16.1 %, respectively however, corresponding increase in wheat was 74.0, 83.0 and 79.0%. The increase in soybean yield through 50 % and 100 % recommended NPK recorded was 2.07 and 16.1%, while that in wheat was 49.2 and 79.0 %. Further increase in fertilizer levels (150 % NPK) resulted in yield reductions. The integration of NPK with FYM could further enhance the yield levels by 26.03 and 90.58 % in soybean and wheat, respectively. The results clearly bring out the impact of balanced nutrition and integrating inorganic fertilizers with organic manures.

Soybean equivalent yield: The maximum soybean equivalent yield was recorded with 100 % NPK plus FYM (3914 kg/ha) which remained at par with 100 % NPK (S-free) (3760 kg/ha). The lowest soybean equivalent yield was associated with control (2529 kg/ha). The high yield and soybean equivalent yield in 100 % NPK plus FYM and 100 % NPK (S-free) could be attributed to the balanced application of nutrients, which could result in favourable yield expressions (Table 1). Since the experimental site regularly received the recommended levels of sulphur through single super phosphate to both the crops over years, there was no appreciable variation in soybean equivalent yield even after skipping sulphur application. Such salutary effect of balanced nutrition has earlier been documented (Ghosh *et al.*, 1998; Tembhre *et al.*, 1998; Joshi and Billore, 2004).

Sustainable yield index (SYI): Sustainable yield index revealed that the soybean cultivation without fertilizer (control) followed by 50% RDF was less affected by seasonal variations (Table 1). However, the application of RDF-Sulphur followed by RDF + hand weeding were the most sensitive to seasonal changes. On the contrary, RDF-S appears to be less influenced by seasonal changes in case of wheat. Assessing the system as a whole, the highest value of sustainable yield index was associated with RDF + FYM leading to added response of the system to seasonal changes as indicated by the highest soybean equivalent yield. The treatment involving RDF + HW followed the trend of RDF + FYM in terms of sustainable yield index. These results also indicated the importance of regular incorporation of organic manure as well as timely hand weeding to contain the weed flora. The role of application of organic sources on the sustainable productivity of crops has earlier been documented (Nambiyar and Abrol, 1989; Billore *et al.*, 1999). The sustainable yield indices also brought forth the range of maximum guaranteed yield (soybean - 24 to 41%, wheat - 51 to 78%, system- 43 to 61%) within the framework of prevailing seasonal changes during experimentation of the potential yield achievable.

Stability analysis: The 'b' values close to unity in case of soybean as compared to drifted values beyond one in case of wheat indicated resilience of soybean to sustain under unfavourable weather conditions (Table 1 and 2). Among different treatments to soybean crop, RDF + FYM, RDF + Zn, RDF + HW, RDF and RDF - S with values less than one, are supposed to perform well even under adverse weather conditions (Billore *et al.*, 1999). It may be seen that for the soybean-wheat system, all the values of 'b' are less than one, indicating that introduction of soybean in cropping sequence provides stability to the systems. In soybean - wheat system, the application of only N followed by RDF + FYM and RDF + HW have performed well under unfavourable environments as indicated by lower "b" values. This is in accordance with the finding of Raun *et al.* (1993).

Table 1 Effect of long term fertilizer application on seed yield, sustainability yield index (SYI), stability (b) of soybean-wheat cropping system

Treatment	Soybean yield (kg/ha)	SYI	b	Wheat yield (kg/ha)	SYI	b	Soybean equivalent yield (kg/ha)	SYI	b
50% NPK	1431	0.27	1.08	3026	0.77	0.84	3112	0.50	0.74
100% NPK	1628	0.38	0.92	3620	0.61	1.54	3639	0.56	0.75
150% NPK	1594	0.34	1.02	3513	0.51	1.71	3545	0.51	0.89
100% NPK + HW	1707	0.40	0.92	3490	0.70	1.16	3646	0.59	0.62
100% NPK + Zn	1654	0.37	0.97	3534	0.66	1.35	3617	0.56	0.71
100% NP	1546	0.32	1.01	3711	0.65	1.44	3607	0.56	0.74
100% N	1602	0.32	1.03	3528	0.78	0.85	3562	0.54	0.60
100% NPK + FYM	1767	0.37	0.98	3865	0.68	1.36	3914	0.61	0.61
100% NPK-S	1736	0.41	0.91	3644	0.58	1.67	3760	0.57	0.75
Control	1402	0.24	1.15	2028	0.61	0.66	2529	0.43	0.79
CD (P=0.05)	65			283			212		

100% NPK = Soybean - 20:26:17 kg NPK/ha, Wheat-120:26:34 kg NPK/ha; HW = Hand weeding

Relative stability: The RDF and RDF + FYM treatments were individually and subjectively chosen for comparisons to assess of the relative stability for the system as a whole (Table 2 and 3). The differences though marginal, control and 150% RDF are relatively less stable than RDF. The effect of inclusion of hand weeding, Zn and FYM has been instrumental in stabilizing yield at higher levels. When the relative stability against RDF + FYM was considered, this treatment was found to be stable over other treatments except RDF + HW and brings out the importance of integrating inorganic with organic nutrition. These results are in agreement with the findings of Raun *et al.* (1993) and Billore *et al.* (1999).

Table 2 Relative stability of RDF and RDF+FYM v/s different treatments in soybean-wheat cropping system

Treatment	SEY		Treatment	SEY	
	b	R^2		b	R^2
RDF v/s 50% RDF	0.05	0.04	RDF + FYM v/s 50% R%DF	-0.32	0.12
RDF v/s 150% RDF	-0.16	0.41	RDF + FYM v/s 150% RDF	-0.28	0.60
RDF v/s RDF + HW	0.13	0.41	RDF + FYM v/s RDF + HW	0.01	0.03
RDF v/s RDF + Zn	0.04	0.03	RDF + FYM v/s RDF + Zn	-0.09	0.19
RDF v/s NP	0.02	0.02	RDF + FYM v/s NP	-0.10	0.23
RDF v/s N	0.09	0.04	RDF + FYM v/s N	-0.04	0.01
RDF v/s RDF + FYM	0.12	0.51	RDF + FYM v/s RDF-S	-0.14	0.31
RDF v/s RDF-S	-0.04	0.13	RDF + FYM v/s Control	-0.14	0.10
RDF v/s Control	-0.01	0.00			

Table 3 Relative stability of RDF+FYM v/s different treatments in soybean-wheat cropping system

Treatment	Soybean		Wheat		Soybean equivalent yield	
	b	R^2	b	R^2	b	R^2
RDF + FYM v/s 50% RDF	-0.07	0.10	0.55	0.42	-0.32	0.12
RDF + FYM v/s 150% RDF	-0.03	0.01	-0.45	0.37	-0.30	0.60
RDF + FYM v/s RDF + HW	0.08	0.14	0.19	0.14	0.02	0.03
RDF + FYM v/s RDF + Zn	0.03	0.02	-0.06	0.01	-0.09	0.19
RDF + FYM v/s NP	-0.00	0.00	-0.06	0.05	-0.10	0.23
RDF + FYM v/s N	-0.04	0.03	-0.27	0.32	-0.04	0.01
RDF + FYM v/s RDF-S	0.09	0.10	0.31	0.09	-0.14	0.31
RDF + FYM v/s Control	-0.16	0.15	0.23	0.05	-0.14	0.10

The integration of FYM with RDF and provision of balanced nutrition by incorporation of Zn not only supplements the nutritional need of crops but also serves as mode of ecological method of sustaining soil productivity. Such integration also extends additional known benefits of improving soil health to provide better environment for cultivation of crops.

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Yield and nutrient uptake of cotton and sunflower as influenced by integrated nutrient management in cotton-sunflower cropping system

K. Mahavishnan, Mangal Prasad[1] and K. Bhanu Rekha

Research Associate, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, A.P.

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Abstract

Field experiments were conducted during *kharif* and *rabi* 2002-03 and 2003-04, respectively at New Delhi under irrigated conditions to formulate a site specific nutrient management package for cotton - sunflower cropping system. The experiment consisted of eight treatments for cotton *viz*; control, 50 % recommended dose of fertilizer (RDF), 100% RDF, mungbean intercrop incorporation (MII), FYM, 50% RDF + MII, 50% RDF + FYM and 50% RDF + FYM + MII. . For succeeding sunflower, each plot of cotton was taken as main plot and it was divided into three sub-plots, wherein three levels of fertilizer *viz.*, 0, 50% and 100% RDF (80:40:40 N, P_2O_5 and K_2O kg/ha) were applied. The trial in cotton was laid out in Randomized Block Design and that of sunflower in Split Plot Design with three replications. Highest values of seed cotton yield; N uptake, P uptake and K uptake were observed with combined application of all the three sources of N. Nutrient management practices on cotton left behind a marked effect on seed yield and nutrient uptake of succeeding sunflower crop. However, direct effect of N application to sunflower was more pronounced than that of residual effect.

Key words: Cropping system, sunflower, cotton, nutrient management

Introduction

Cotton (*Gossypium hirsutum* L.) the king of fibre crops and a crop of prosperity, is an industrial commodity of worldwide importance. It is an important cash crop of India, grown by 4m farmers on an estimated 7.4 m. ha (Mayee *et al.*, 2004). Sunflower cultivation is becoming much popular because of its short duration, photo-insensitivity, wide adaptability and drought tolerance (Hegde, 2000).

Cotton-sunflower sequence is gaining popularity whenever the sowing of the traditional *rabi* season crops is delayed. Since both the crops are of exhaustive nature, there is a need to develop profitable and environmentally safe nutrient management strategies. While devising fertilizer recommendations, it is necessary to consider cropping sequence rather than an individual crop. As the nutrient requirements of crops differ, the utilization pattern of applied nutrients is to be studied for deciding on a suitable supplementary dose in crop sequence. Use of an appropriate combination of inorganic fertilizers and organic manures could conserve nutrients otherwise lost from fertilizer application (Ramparkash and Prasad, 2000). Keeping the above points in view, a study was conducted to find out the effect of integrated nutrient management in cotton and its residual effect on sunflower.

Materials and methods

The experiment was laid out in the Top Block 6E of the research farm, Indian Agricultural Research Institute (IARI), New Delhi (28°58' N latitude; 77°10' E longitude and 228.16 m above mean sea level) during 2002-2003 and 2003-2004 (*Kharif* and *Rabi*). The soil of the experimental site was sandy loam in texture, low in available N, medium in P and K content. The experiment consisted of eight treatments for cotton (Table 1). For succeeding sunflower, each plot of cotton was taken as main plot and it was divided into three sub-plots, wherein three levels of fertilizer *viz.*, 0, 50% and 100% RDF (80:40:40 N, P_2O_5 and K_2O kg/ha) were applied randomly. The trial in cotton was laid out in Randomized Block Design and that of sunflower in Split Plot Design with three replications.

Farmyard manure 12 t/ha was applied as per treatments. Green manure crop (green gram) was grown between two rows of cotton and turned down at 40 days after sowing. For cotton 50 % N was applied, as basal and remaining half was top-dressed at square initiation stage. A uniform dose of 30 kg each of P_2O_5 and K_2O/ha were applied as basal dose. For sunflower, basal dose of fertilizers, consisting of half the dose of N (40 kg/ha) and full doses of P (40 kg/ha) and K (40 kg/ha) were applied as basal and the rest half of N was supplied at 40 DAS. The N, P and K content were estimated with standard procedure and the uptakes of nutrient were calculated.

[1] Principal Scientist, Division of Agronomy, Indian Agricultural Research Institute, Pusa, New Delhi-110 012.

Results and discussions

Cotton

Seed cotton yield: Seed cotton yield increased significantly with each successive increment in N dose up to 100% RDF (Table 1 and Fig.1). The highest seed cotton yield (2347 and 2693 kg/ha during 2002 and 2003, respectively) was observed with combined application of all the three sources of N, was on par with 50% RDF + FYM and 100% RDF alone. The next best treatment was combined application of 50% RDF with FYM. These results indicated the beneficial effect of FYM addition along with fertilizer. Organic sources play 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 capability These organic sources also supply some micronutrients and growth promoting substances, which might have helped in higher boll retention and improved boll weight. (Katkar *et al.*, 2002).

Nitrogen uptake: Different N management practices resulted in perceptible variation in N uptake of cotton (Table 1). Maximum N removal (93.6 and 113.7 kg/ha during 2002 and 2003, respectively) was recorded with combined application of 50% RDF, FYM and Mungbean Intercrop (Fig. 2). Increased nitrogen uptake with conjunctive use of organic sources with inorganic fertilizers might be due to consistent supply of nitrogen to the crop and decreased loss of releasing nitrogen during decomposition of organic manures (Blaise and Singh, 2004).

Phosphorus uptake: Maximum P uptake (139 and 165 kg/ha during 2002 and 2003, respectively) was observed with combined application of 50% RDF and FYM coupled with Incorporation of Intercrop and was significantly superior over rest of the treatments, except 50% RDF + FYM (Table 1). Enhanced P uptake with conjunction use of FYM and inorganic N might be due to organic acids produced during decomposition of organic matter are capable of releasing the phosphorus associated with clay minerals. Besides this, organic manures form complexes with iron, aluminium ions and hydrous oxides thereby preventing its fixation as inorganic complexes and also the use of well decomposed FYM might have resulted in the formation of phospho-humic complexes which are more easily assimilated by the plants or isomorphous replacement of phosphate ions by humate ions by coating the sesquioxide particles through the formation of protective cover which reduces the phosphate fixing capacity of the soil and improved the availability and uptake of phosphorus (Tarhalkar *et al.*, 1996).

Potassium uptake: Maximum K uptake of 69.6 and 80.9 kg/ha was recorded with combined application of all the three sources of N. During both the years' minimum K uptake were recorded with control. Increased potassium uptake with organic sources treated plots might be due to the priming effect, such that organics on decomposition releases organic acids which solubilize native i.e. fixed and non exchangeable form of K and change the soil solution with K ions at later stages of crop growth (Singh *et al.*, 1999).

Sunflower

Yield attributes: The differences observed in growth parameters across different treatments were also reflected in yield attributes (Table 2). Capitulum size and seed weight/capitulum of sunflower were increased significantly due to the residual effect of the INM on preceding cotton crop in the sequence, but the number of seeds/capitulum and 1000 seed weight did not increase significantly. Maximum residual effect in terms of improving yield attributes were observed when FYM was applied either alone or in combination with 50% RDF and mung incorporation followed by 100% RDF. This could be attributed to higher residual nutrient availability and subsequent better uptake that might have resulted in higher dry matter accumulation and improved yield attributes. Similar results were indicated by Patidar and Mali (2001).

Yield attributes increased significantly with successive higher N to sunflower up to 100% RDF. As N application increased photosynthetic area as well as accumulation of photosynthates in capitulum of sunflower, it might have resulted in larger capitulum. Adequate N might have increased number of seeds per capitulum probably by preventing the degeneration of florets where seed development takes place Jat and Giri (2000).

Seed yield: Residual effect of treatments involving FYM found to be more pronounced over non-FYM treatments (Table 3). Combined application of 50% RDF, FYM and Mungbean Intercrop Incorporation recorded significantly higher seed yield over rest of the treatments, except 50% RDF + FYM. Favorable effect of FYM application either alone or in combination with other N sources could be attributed to improved growth and yield attributes caused by better soil condition and subsequent higher nutrient availability (Ramparkash and Prasad, 2000).

Successive increment of N increased sunflower yield significantly and was highest with 100% RDF (2200 and 1260 kg/ha during 2002-03 and 2003-04, respectively). Significant increase in seed yield with higher level of N could be ascribed to higher N availability and uptake with corresponding higher N levels and subsequent greater production of photosynthates, which ultimately led to higher biomass production (Edara and Patel, 2000).

Fig. 1 Seed cotton yield (kg/ha) as influenced by integrated nutrient management practices

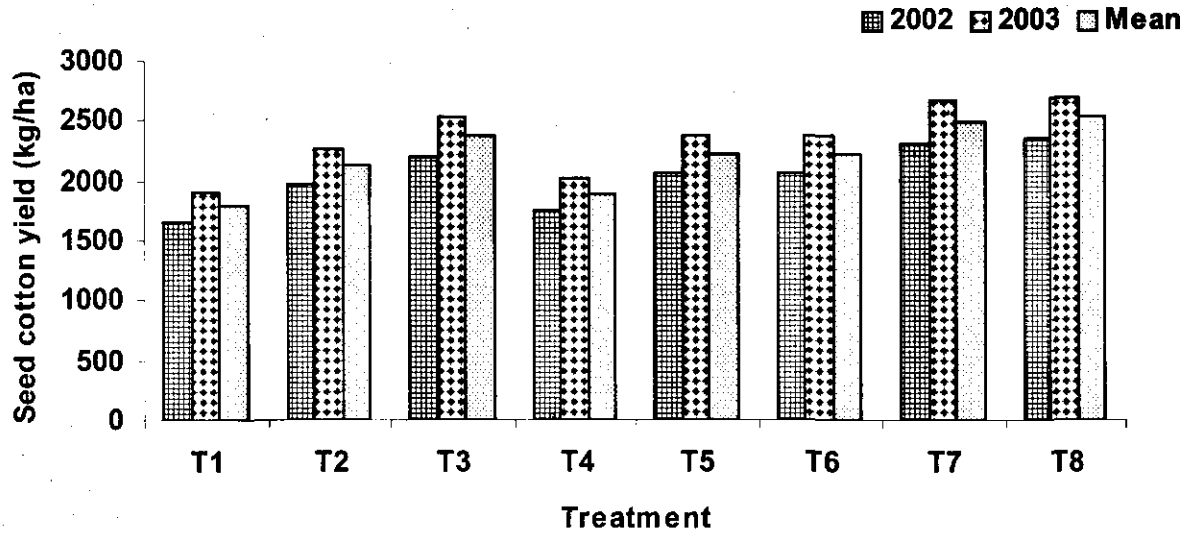

Fig.2 Mean nutrient uptake of cotton as influenced by integrated nutrient management practices

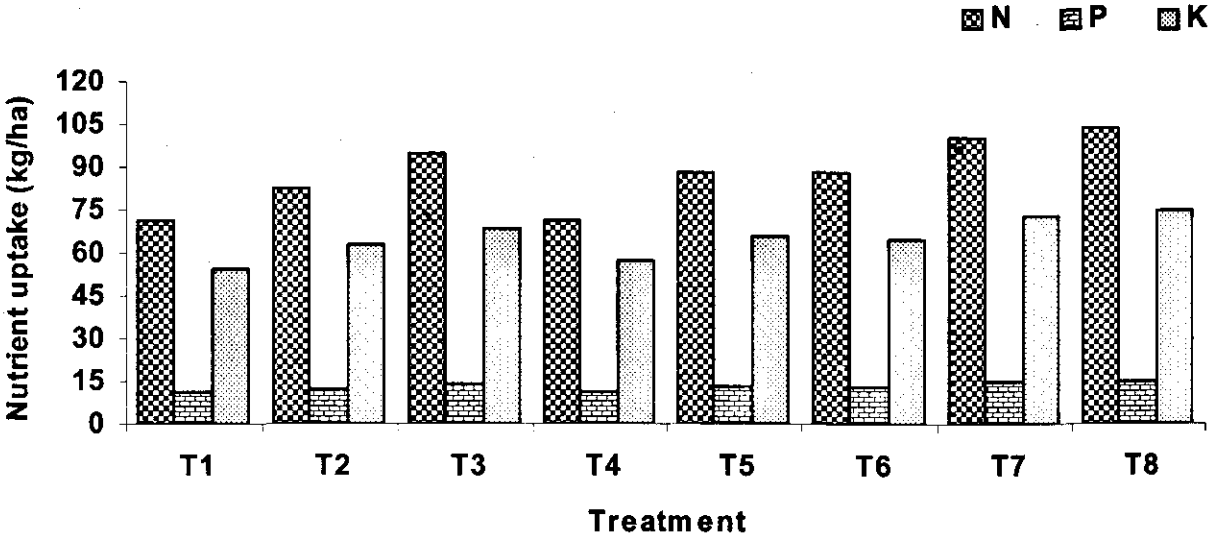

Table 1 Effect of organic and inorganic sources of N on seed cotton yield, total N, P and K uptake of cotton

Treatment	Seed cotton yield (kg/ha)			N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	2002	2003	Mean	2002	2003	2002	2003	2002	2003
T_1 : Control	1660	1914	1787	65.5	75.6	10.3	11.4	52.3	56.5
T_2 : 50% RDF	1972	2267	2119	77.6	88.2	11.8	13.0	59.8	65.1
T_3 : 100% RDF	2201	2539	2370	87.5	101.0	13.1	14.7	65.0	72.7
T_4 : Mungbean intercrop incorporation (MII)	1752	2007	1879	63.3	79.4	10.8	11.7	54.9	59.8
T_5 : Farm yard manure (FYM)	2069	2384	2226	81.5	94.2	12.5	13.9	62.2	68.9
T_6 : 50% RDF + MII	2058	2362	2210	80.7	95.0	12.3	13.9	61.7	68.3
T_7 : 50% RDF + FYM	2312	2661	2486	90.9	110.3	13.7	16.1	68.2	78.8
T_8 : 50% RDF + FYM + MII	2347	2693	2520	93.6	113.7	14.0	16.5	69.6	80.9
SEm ±	76	63	59	1.5	1.8	0.2	0.2	1.0	1.1
CD (P=0.05)	171	174	167	4.6	5.8	0.7	0.7	3.0	3.4

Table 2 Residual and direct effect of treatments on yield attributes of sunflower

Treatment	Capitulum size (cm)		No. of seeds/capitulum		Seed weight/capitulum		1000 seed weight (g)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Residual effect								
T_1 : Control	12.9	11.3	669	486	25.3	15.1	38.5	28.0
T_2 : 50% RDF	13.2	11.5	677	494	25.9	15.3	38.6	28.2
T_3 : 100% RDF	13.3	11.8	681	499	26.4	15.4	38.8	28.3
T_4 : Mungbean intercrop incorporation (MII)	13.6	11.9	689	507	27.4	15.7	38.9	28.3
T_5 : Farm yard manure (FYM)	13.9	12.2	699	516	27.9	16.4	39.0	28.5
T_6 : 50% RDF + MII	13.7	12.1	693	510	27.5	15.9	38.9	28.4
T_7 : 50% RDF + FYM	14.1	12.3	710	521	28.3	16.8	39.1	28.6
T_8 : 50% RDF + FYM + MII	14.3	12.5	716	526	29.0	17.5	39.1	28.8
SEm ±	0.2	1.2	16	17	0.3	0.1	0.5	0.4
CD (P=0.05)	0.4	0.4	NS	NS	0.9	0.4	NS	NS
Direct effect								
Control	12.7	11.2	665	474	22.7	14.2	36.6	27.0
50% RDF	13.7	12.0	697	507	26.2	15.8	38.6	29.1
100% RDF	14.6	12.5	732	541	32.8	18.0	41.4	32.5
SEm ±	0.1	1.1	15	15	0.2	01	0.4	0.4
CD (P=0.05)	0.3	0.3	NS	NS	0.6	03	1.2	1.2

Table 3 Residual and direct effect of treatments on seed yield, total N, P and K uptake of sunflower

Treatment	Seed yield (kg/ha)			N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	2002-03	2003-04	Mean	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Residual effect									
T_1 : Control	1810	1030	1420	83.9	58.8	26.1	16.9	83.4	69.3
T_2 : 50% RDF	1830	1040	1440	84.8	59.6	26.2	17.2	84.1	70.0
T_3 : 100% RDF	1840	1060	1450	85.4	59.5	26.4	17.5	84.4	70.7
T_4 : Mungbean intercrop Incorporation (MII)	1890	1090	1490	90.1	61.8	27.2	17.9	66.6	71.9
T_5 : Farm yard manure (FYM)	1980	1170	1580	91.4	66.2	28.4	19.7	88.7	76.1
T_6 : 50% RDF + MII	1930	1100	1510	89.5	62.5	27.7	18.2	87.7	72.5
T_7 : 50% RDF + FYM	2040	1190	1620	93.6	67.2	29.1	20.1	89.7	76.7
T_8 : 50% RDF + FYM + MII	2080	1240	1660	95.7	69.5	29.7	20.8	91.1	78.4
SEm ±	35	31	34	0.9	0.7	0.2	0.2	0.6	0.7
CD (P=0.05)	81	72	89	3.1	2.4	0.6	0.6	2.7	2.6
Direct effect									
Control	1650	960	1310	75.2	52.8	22.8	14.7	76.5	63.6
50% RDF	1930	1130	1530	88.1	64.7	27.4	19.2	86.1	74.8
100% RDF	2200	1250	1730	104.7	71.8	32.6	21.7	98.3	81.3
SEm ±	41	37	48	0.6	0.5	0.1	0.1	0.6	0.6
CD (P=0.05)	120	108	109	1.9	1.6	0.3	0.3	1.8	1.8

Harvest index: Nitrogen management practices followed for preceding cotton could not affect harvest index of sunflower significantly during first year of study, but influenced significantly during second year of experimentation. Residual effect of FYM applied in combination with inorganic N or inorganic N and MII resulted in comparatively higher harvest index of sunflower over other treatments.

Direct application of N to sunflower significantly increased the harvest index during both the years. Application of 100% RDF resulted significantly higher harvest index (40.7 and 28.6 during 2002-03 and 2003-04, respectively) over 50% and control.

Nitrogen uptake: N removed by sunflower varied significantly due to residual effect of organic and inorganic sources of N applied to cotton. Highest total N uptake of 95.68 and 69.49 kg/ha was recorded with 50% RDF + FYM + MII, which was significantly superior over rest of the treatments except 50% RDF + FYM. Combined application of all the sources of N recorded 13.9 and 18.2% higher N uptake over control during 2002-03 and 2003-04 respectively.

N uptake increased significantly with each increment in N levels up to 100% RDF. The highest total N removal of 104.68 and 71.84 kg/ha during respective years of study was recorded with 100% RDF.

Phosphorus uptake: Highest total P uptake of 95.68 and 69.49 kg/ha during 2002-03 and 2003-04, respectively was recorded with 50% RDF + FYM + MII in both the years and was comparable with the application of 50 % RDF +FYM.

Direct application of N significantly enhanced the total phosphorus uptake in both the years. Highest total phosphorus uptake of 32.64 and 21.74 kg/ha during 2002-03 and 2003-04, respectively was recorded with 100% RDF, which was significantly superior over 50% RDF as well as control.

Potassium uptake: Residual effect of N management practices adapted to preceding cotton crop on potassium uptake of succeeding sunflower was significant during both the years . During both the years of study highest total potassium uptake was recorded with 50% RDF + FYM + MII.

Effect of direct application of N on potassium uptake was significant during both the years. Application of 100% RDF was significantly superior over 50% RDF as well as control.

The highest and lowest potassium uptake of 98.27, 81.27, 76.47 and 63.57 kg/ha was with 100% RDF and control during 2002-03 and 2003-04, respectively.

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Biochemical basis of white stem rot, *Sclerotinia sclerotiorum* resistance in rapeseed-mustard

Sanjay Guleria and Ashok Kumar

CSK H.P. Krishi Vishvavidyalaya, Shivalik Agricultural Research and Extension Centre, Kangra-176 001, HP

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Abstract

Study was conducted to know the level of various biochemical constituents implicated in defense response such as free and wall bound phenolics, lignin content and total sugars in leaf and stem tissue of rapeseed-mustard cultivars, resistant (JTC-1 and PCC 5) and susceptible (Neelam and Sheetal) to stem rot (*Sclerotinia sclerotiorum*). In addition to this, total sugar content was also determined in flower petals. The level of free phenols, wall bound phenols and lignin was higher in stem rot resistant cultivars, whereas, the susceptible cultivars possessed higher level of total sugars, which also had higher disease intensity. Similarly, flower petals of susceptible cultivars had higher level of total sugars as compared to resistant cultivars.

Key words: *Sclerotinia sclerotiorum*, phenols, lignin, rapeseed-mustard

Introduction

Among nine annual oilseed crops grown in India, rapeseed-mustard with an acreage of 4.5 m.ha, account for 19% of area and 23% of production (Damodaram and Hegde, 2002). Among the various factors responsible for the low productivity of this crop, in India diseases and pests are the important yield destabilizing factors. So for, *Alternaria* blight and white rust were only considered to be the diseases of economic importance in this crop, however, as a result of intensive cropping and overall shift in weather conditions, white stem rot caused by *Sclerotinia sclerotiorum* (Lib.) de Bary is becoming a serious disease in many parts of the country including Himachal Pradesh. The pathogen primarily attacks the stems of the plant at flowering stage and cause heavy yield losses (Roy and Saikia, 1976). A survey of *Sclerotinia* stem rot disease in the experimental farm of Shivalik Agricultural Research and Extension Centre, Kangra (Himachal Pradesh) during 2001-02 revealed that some of the cultivars belonging to *Brassica carinata* were resistant, whereas those belonging to *Brassica napus* were susceptible or highly susceptible.

The aim of the present study was to identify biochemical resistance markers that can be used in directed breeding programmes for *Brassica* species to naturally increase stem rot resistance.

Material and methods

Four cultivars of rapeseed-mustard, *viz.*, JTC-1 and PCC-5 belonging to *B. carinata* (Resistant), Sheetal and Neelam of *B. napus* (susceptible) were planted in plot size of 15 x 4.5 m^2 in last week of October at the experimental farm of Shivalik Agricultural Research and Extension Centre, Kangra (Himachal Pradesh) during 2002-03 in the field having previous history of severe infection of *Sclerotinia* stem rot disease. A spacing of 30 cm between the rows and 15-20 cm between the plants was maintained. Recommended doses of NPK fertilizers (90:60:40 kg/ha) were applied. Field was irrigated frequently to maintain the humid conditions. Plant samples for analysis of various biochemical parameters were collected on 100 days after sowing at the full flowering stage of the crop coinciding with the germination of sclerotia of the fungus in the soil and initiation of infection for disease development. Five healthy plants from each variety were randomly selected for the analysis of various biochemical parameters. For analysis of the biochemical constituents of stem, lower portion (25 cm) of the stem was taken, whereas for leaf analysis, leaves of the lower half of the stem were considered. Petals from the flowers of the selected plants were removed for the analysis of total sugar content. Per cent disease intensity of stem rot was calculated by counting the number of infected plants/plot (Pathak *et al.*, 2002). Free and wall bound phenolics were determined according to Kofalvi and Nassuth (1995). Lignin was determined according to Doster and Bostock (1988). Total sugars were estimated by the method of Clegg (1956).

Results and discussion

The data of per cent disease intensity (Table 3) of *Sclerotinia* stem rot in different cultivars revealed that disease was minimum in case of resistant cultivars *viz.*, JTC-1 (4.3%) and PCC-5 (6.8%) as compared to susceptible cultivars Neelam (22.8%) and Sheetal (28.6%). *Sclerotinia* stem rot resistant cultivars *viz.*, JTC-1 and PCC-5 were having higher free phenolic (Table 1) content (0.50 and 0.48 mg/100 mg dry weight, respectively) in stem tissue. On the contrary, free phenolic content in the stem tissues of *Sclerotinia sclerotiorum* susceptible cultivars *viz.*, Neelam and Sheetal was found to be low (0.40 mg/100 mg

dry weight). Similarly, JTC-1 and PCC-5 had higher level of wall bound phenols (0.18 mg/100 mg dry weight) in the stem tissues as compared to susceptible cultivars Neelam and Sheetal (0.16 mg/100 mg dry weight).

Free and wall bound phenolic content was also determined in leaves (Table 2) of *Sclerotinia sclerotiorum* resistant (JTC-1 and PCC-5) and susceptible (Sheetal and Neelam) *brassica* cultivars. Free phenolic content was found to be higher in leaves of JTC-1 and PCC-5 (3.6 and 3.2 mg/100 mg dry weight, respectively) and lower in Neelam and Sheetal (2.6 mg/g dry weight). With regard to wall bound phenolics in leaf tissues, their level was also found to be higher in JTC-1 and PCC-5 (0.64 and 0.60 mg/100 mg dry weight, respectively). Susceptible cultivars *viz.*, Neelam and Sheetal possessed lower level of wall bound phenols (0.43 and 0.42 mg/100 mg dry weight, respectively). Phenols have been reported to be involved in the disease resistance responses against potential pathogens in many field crops (Brahmachari and Kolte, 1993). Either they are directly toxic to the pathogens or their oxidation products inhibit pectinolytic enzymes (Sharma *et al.*, 1990). Brassica cultivars *viz.*, JTC-1 and PCC-5 resistant to Sclerotinia stem rot were found to have higher lignin content [223.2 and 217.0 LTGA (A_{280}/g dry weight), respectively] in the stem tissue as compared to susceptible cultivars *viz.*, Neelam and Sheetal [149.2 and 150. LTGA (A_{280}/g dry weight), respectively]. Similarly, leaf tissue of JTC-1 and PCC-5 contained higher lignin concentration *viz.*, 92.0 and 90.0 LTGA (A_{280}/g dry weight), respectively, whereas, Neelam and Sheetal contain lower concentration of lignin *viz.*, 77.2 and 75.8 LTGA (A_{280}/g dry weight), respectively. Higher production of lignin after pathogen ingress has been implicated in consolidation of physical barriers (Cell wall) against the invading microorganisms (Saharan and Saharan, 2001). The stronger cell wall may exclude the pathogenic microbes at very initial stage of attempted infection (Nicholson and Hammerschmidt, 1992). Lignin concentration has been shown to increase in several host-pathogen interactions after infection (Southerton and Deverall, 1990).

Table 1 Biochemical constituents in stem tissue of *Sclerotinia* stem rot resistant and susceptible *brassica* cultivars

Cultivar**	Free phenols* mg/100 mg dry weight	Wall bound phenols mg/100 mg dry weight	Lignin concentration [LTGA(A_{280}/g dry weight)]	Total sugars (mg/100 mg dry weight)
JTC-1 ®	0.50 (4.0)	0.18 (2.4)	223.2	4.1 (10.7)
PCC-5 ®	0.48 (4.0)	0.81 (2.4)	217.0	4.3 (12.0)
Neelam (S)	0.40 (3.6)	0.16 (2.3)	149.2	5.4 (13.5)
Sheetal (S)	0.40 (3.6)	0.16 (2.3)	150.0	5.4 (13.3)
CD (P=0.05)	(0.07)	0.02)	6.3	(0.12)

* Values in parenthesis are the mean after arc sine transformation; ** Values are the mean of five replicates

Table 2 Biochemical constituents in leaf tissue of *Sclerotinia* stem rot resistant and susceptible *brassica* cultivars

Cultivar**	Free phenols* mg/100 mg dry weight	Wall bound phenols mg/100 mg dry weight	Lignin concentration [LTGA(A_{280}/g dry weight)]	Total sugars (mg/100 mg dry weight)
JTC-1 ®	0.50 (4.0)	0.18 (2.4)	223.2	4.1 (10.7)
PCC-5 ®	0.48 (4.0)	0.81 (2.4)	217.0	4.3 (12.0)
Neelam (S)	0.40 (3.6)	0.16 (2.3)	149.2	5.4 (13.5)
Sheetal (S)	0.40 (3.6)	0.16 (2.3)	150.0	5.4 (13.3)
CD (P=0.05)	(0.07)	0.02)	6.3	(0.12)

* Values in parenthesis are the mean after arc sine transformation; ** Values are the mean of five replicates

Table 3 Biochemical constituents in flower petals of *Sclerotinia* stem rot resistant and susceptible *brassica* cultivars/disease reaction of different *brassica* cvs. to stem rot

Cultivar**	Total sugars** (mg/100 mg dry weight)	Disease reaction	Disease intensity (%)
JTC-1 ®	8.1 (16.5)	R	4.3
PCC-5 ®	8.4 (16.8)	R	6.8
Neelam (S)	11.1 (19.4)	S	22.8
Sheetal (S)	11.2 (19.6)	S	28.6
CD (P=0.05)	(0.2)	-	-

* Values in parenthesis are the mean after arc sine transformation
** Values are the mean of five replicates

Plant can produce a number of antifungal and fungistatic secondary metabolites. Upon infection changes can occur in both constitutive compounds such as phenolics and also *de novo* synthesis of antifungal compounds e.g. phytoalexins. It is known that certain biochemical events occur in resistant reactions to fungal infection resulting in large increases in the level of both free and wall bound phenols. This is also coupled with the enhanced production of lignin for the consolidation of physical barriers (Bennett and Wallsgrove, 1994).

Total sugar content in the stem tissue of *S. sclerotiorum* resistant *brassica* cultivars *viz.*, JTC-1 and PCC-5 was found to be low (4.1 and 4.3 mg/100 mg dry weight, respectively) as compared to susceptible cultivars *viz.*, Neelam and Sheetal (5.4 and 5.3 mg/100 mg dry weight, respectively). Similarly, total sugar content in leaf tissue of JTC-1 and PCC-5 (7.4 mg/100 mg dry weight and 7.8 mg/100 mg dry weight, respectively) was found to be lower as compared to *Sclerotinia* stem rot susceptible brassica cultivars *viz.*, Neelam and Sheetal (10.0 and 9.9 mg/100 mg dry weight, respectively).

Total sugar content was also determined in flower petals of *Sclerotinia* resistant and susceptible cultivars. Flower petals of resistant cultivars *viz.*, JTC-1 and PCC-5 contained lower amount of total sugars (8.1 and 8.4 mg/100 mg dry weight, respectively) as compared to susceptible cultivars *viz.*, Neelam and Sheetal (11.1 and 11.2 mg/100 mg, respectively). Higher level of total sugars has been implicated in susceptibility to pathogenic microbes (Dhavan *et al.*, 1981). Guleria and Kumar (2003) also reported the higher level of total sugars in white rust susceptible *brassica* cultivars as observed in present study. From the above study, it is concluded that phenols and lignin may be involved in imparting resistance to stem rot in rapeseed-mustard. As fallen flower petals are absolutely necessary for ascospore germination and initiation of infection low sugar content in petals can be a valuable biochemical market in *brassica* for stem rot disease.

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Studies on seed colouring in castor, sunflower and safflower

V.A. Tonapi, P. Harinath Babu[1], N.A. Ansari[1], S. Varanavasiappan, Ch. Ravinder Reddy[2], S.S. Navi[3] and N. Seetharama

National Research Centre for Sorghum, Rajendranagar, Hyderabad-500 030, A.P

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Abstract

The investigations on the effect of seed colouring on castor (*Ricinus communis* L.), sunflower (*Helianthus annuus* L.) and safflower (*Carthamus tinctorius* L.) seeds encompassing 25 dyes were conducted to identify non-deleterious and deleterious dyes based on their effect on seed quality. The dyes namely Rhodamine-B and Erichro black-T for castor, Rhodamine-B and Cotton blue for sunflower and Rhodamine-B, Fuchsine and Neutral red for safflower are the best dyes for seed colouring at 0.75% concentration. In this paper we discuss effect of seed colouring on seed quality of castor, sunflower and safflower seeds and their resultant implications for Indian seed industry.

Key words: Seed colouring, castor, sunflower, safflower

Introduction

The history of seed colouring in the international arena suggests that colour standards in Canada, United States of America and other European countries were established as per policies regarding colouration of treated seeds and trade memorandums that were issued on July 13, 1967. Different types of dyes have been used for colouring seeds, including acids dyes, basic dyes, direct dyes and pigments. The basic dyes are used most frequently because of their strong, brilliant shades, which can provide distinctive colour in spite of the natural colouration of the seeds, and because of their economy, on an equal colour basis, versus other dye types. The dye is added to the seeds as solution or suspension and blended to give an even coverage. The processors colour seeds because it is required by law to avoid accidental use of treated seeds as food or feed. Some people colour seeds with a specific colour as a trademark, just to identify their seeds. But, to use such dyes, which in fact are chemical formulations, it is necessary to prove that they are non-toxic with respect to seed germination, vigour potential and viability.

There are very few studies in India on seed colouring (Tonapi and Karivaratharaju, 1994) in sorghum, Vivekanandan (1999) and Basavaraj and Kurdikeri (1999) in soybean to establish indigenous colour standards to pave the way for colouring the seeds by incorporating the provisions in the seed quality control and seed trade in India. In this paper we discuss effect of seed colouring on seed quality of castor, sunflower and safflower seeds and their resultant implications for Indian seed industry.

Materials and methods

The investigations on the effect of seed colouring on castor (Cv.PCS-4), sunflower (Cv. Morden and BSH-1), and safflower seeds (Cv. Bheema) encompassing 25 dyes were conducted during, 2001-02 to develop and recommend colour standards after assessing their effect on seed quality.

Dyes used in seed colouring: A total of 25 dyes namely Indigo caramine ($C_{16}H_8N_2O_2$ $(So_3Na)_2$), Titan yellow (Dehydrothio-P-toluidine), Methyl orange($Me_2NC_6H_4N$: $NC_6H_4SO_2Na$), Methyl Red ($Me_9NC_6H_4N$: NC_6H_4COOH), Nigrosine ($C_{38}H_{27}N_3$), Erichro Black-T ($C_{20}H_{12}N_3O_7Sna$), Ammonium purpureate ((Mureoxide) $(NH_4)_4$ P_2O_7), Boromocresol green ($C_{21}H_{14}Br_4O_5S$), Bromocresol purple ($C_{19}H_{10}Br_2Cl_2O_2S$), Crystal violet ($C_{25}H_{30}ClN_3$), Malachite green ($Me_2NC_6H_4C_6H_5C$: $NC_6H_4Me_2Cl$), Congo red ($C_{32}H_{22}O_6N_6S_2Na_2$), Phenol Red ($C_{19}H_{14}O_5S$), Cotton Blue ($C_{32}H_{25}N_3O_9S_3Na_2$), Gentian violet ($C_{25}H_{30}ClN_3$), Fuchsine ($C_{20}H_{17}N_3Na_2O_9S_3$), Methylene Blue ($C_{19}H_{10}Br_2C_{12}O_25$), Rhodamine-B ($C_{28}H_{31}Cl$ N_2O_3), Neutral red ($Me_2NC_6H_3N$: $NC_6H_2MeNH_2.HCl$), Fast green ($C_{37}H_{34}N_2Na_2O_{10}S_3$) along with commercially available dyes in the market namely Kumkum, Yellow, Pink, Blue and Brick red and control (no colouring) were used to develop and recommend color standards after assessing their effect on seed quality.

Preparation of the dye solution: All the dyes were prepared at 0.75% concentration by dissolving 0.25 g of dye in 16.5 ml water and 15.0 ml ethylene glycol (Tonapi, 1988). This concentration was arrived at based on seed colouring trails at the range from 0.25 to 1.5% concentrations.

[1] Dept. of Genetics and Plant Breeding & Seed Science and Technology, Acharya N.G. Ranga Agril. University, Rajendranagar, Hyderabad-500 030, AP.
[2] International Crops Research Institute for Semi Arid Tropics, Patancheru-502 324, AP.
[3] Dept. of Plant Pathology, 351 Bessey Hall, College of Agriculture, Iowa State University, Ames, Iowa-50011-1020, USA

Seed colouring procedure: In order to obtain the desired dye intensity, individual dye solutions in specified quantities were added on to 10 g of seeds of each variety placed in a 1000 ml Erlenmayer flask, slowly down the sides of flask with a pipette. The flask was shaken for 3-5 minutes to give uniform coverage of individual dye to the seed. The seeds thus coloured were subjected for laboratory evaluation to assess the effect of these dyes on seed germination, seedling traits, field emergence, electrical conductivity, speed of germination and enzyme activity in seeds to identify the non-deleterious dyes.

Survey to identify best colour: The standardization of 0.75% concentrations was based on attractive colouration imparted on to the seeds. Based on the shine, luster, deep uniform and vibrant colouration imparted on to the seeds of castor, sunflower and safflower, a survey to know the final choice and approval of the group encompassing seed corporations, seed growers, processors and seed traders was conducted with the sample size of one hundred individuals.

Observations: *The effect of seed colouring dyes on seed germination, root and shoot length of seedlings, dry weight* and seedlings, speed of germination, field emergence and speed of germination was recorded following International Seed Testing Association Standards (Anonymous, 1985). Seed vigour was assessed through vigour index calculated as the product of root length and seed germination and expressed as absolute value (Abdul Baki and Anderson, 1973).

Electrical conductivity of seed leachate (Presley, 1958), *α-amylase activity* (Simpson and Naylor, 1962) and Dehydrogenase activity (Kittock and Law, 1968) were estimated to assess the effect of dyes on biochemical composition of seeds. All the tests were conducted in four replications consisting 400 seeds. Fisher's method of analysis of variance was applied for data analysis.

Results and discussion

Influence of seed colouring on germinative, physiological and biochemical indices of seeds in castor, sunflower and safflower exhibited both positive and deleterious influences on root-shoot and whole seedling length, dry weight of seedlings, vigour index, speed of germination and electrical conductivity of seed leachate for castor, sunflower and safflower are presented respectively in tables 1, 2 and 3. The influence of dyes on seed germinability in laboratory, field, and in d-manitol soak test, chemical soak test and exhaustion test of castor, sunflower and safflower are presented in figures 1,2 and 3 respectively. The results are in line with the findings of Saraswathi (1994), Tonapi and Karivaratharaju (1994), and Tonapi *et al.* (2004).

The detailed analysis of the data inferred to categorise all the 25 dyes into best, mid range and most deleterious in relation to their effect on seed quality. The dyes namely Rhodamine, Erichro black-T, Nigrosine, Cotton blue, Mureoxide and Neutral red were the best and most favoured dyes in view of their promoting effect on seed quality in castor. The most deleterious dyes were identified in castor as Natural dyes Pink and Kumkum and the others were in mid range. The dyes namely Rhodamine-B, Congo red, Bromocresol purple, Nigrosine, Phenol red and Cotton blue were identified as the best and most favoured dyes in view of their promoting effect on seed quality in sunflower. The most deleterious dyes in sunflower are natural dyes Pink, Yellow and Brick red. Remaining dyes were classified as mid range in terms of the fact that they were not very deleterious but they were certainly declined the total seed quality components significantly when compared to most favoured dyes. The dyes namely Rhodamine-B, Fuchsine and Neutral red are the best and most favoured dyes in view of their promoting effect on seed quality in safflower. The most deleterious dyes in safflower natural dyes Blue and Kumkum which are injurious to the seeds as expressed in seed germination, field emergence and the total deleterious impact on physiological and biochemical parameters involved in this investigation. The remaining dyes were classified as mid range.

However, the promotory effect of some of the dyes may be due to the probable stimulatory effect on enzymes like α-amylase and dehydrogenase activity and their release during seed germination, because of which the faster rate of growth of seedlings becomes evident, as seen in the present study; in the form of higher root length, shoot length, and maximum dry weight of seedlings, including vigour index. The inhibitory toxic effect of Natural dyes Kumkum, Blue, Pink, Yellow, Brick red and Methyl red indicated the entry of the dye, though in very small quantity, into the seed, due to which probably the active chemical ingredient groups of each of these deleterious dyes might have interfered with seed energetics, enzyme release and macromolecule degradation in seed during seed germination to result in the form of maximum number of abnormal seedlings, lower vigour and decreased performance under stress conditions as evaluated through exhaustion test (Tonapi *et al.* 2004).

The most favoured seed dyes out of best dyes, already selected in terms of their influence on seed quality and on the basis of visual colour index and hues imparted, are Rhodamine-B and Erichro black-T in castor, Rhodamine-B and Cotton blue in sunflower, and Rhodamine-B, Fuchsine and Neutral red in safflower.

Table 1 Influence of seed colouring on seed germination (%), *seedling growth and* vigour index in castor (Cv. PCS – 4)

Name of the dye	Root length (cm)	Shoot length (cm)	Whole seedling length (cm)	Dry weight of seedling (g)	Vigour index (RL x G%)	Speed of germination	EC (μ mhos/cm)
Rhodamine-B	15.0	13.4	28.4	0.67	1365	14.2	329
Cotton Blue	15.5	13.5	29.0	0.64	1316	13.4*	330
Fuchsine	13.1	11.3	24.5*	0.56	934*	11.0*	330
Neutral Red	12.4	12.4	24.8*	0.51	1010*	12.0*	329
Gentian violet	13.3	12.8	26.2	0.36*	905*	12.7*	332*
Methylene Blue	13.6	13.4	27.0	0.43*	762*	9.7*	335*
Crystal violet	15.6	12.8	28.5	0.46*	1278	13.5*	329
Congo red	11.8*	10.5*	22.4*	0.53*	1011*	13.3*	330
Fast green	13.3	11.0	24.3*	0.57*	990*	15.0	330
Bromocresol purple	12.2	11.4	23.6*	0.61	927*	13.7*	330
Phenol Red	12.6	12.3	24.9*	0.73	828*	12.9*	337*
Nigrosine	16.2	11.8	28.0	0.51*	1205*	15.1	330
Erichro black-T	16.8	14.9	31.8	0.52*	1101*	13.3*	337*
Murexoxide (Amm.pur)	9.8*	9.3*	19.1*	0.71	837*	16.2	329
Bromocresol green	12.6	12.7	25.3	0.81	955*	13.2*	330
Malachite green	11.6*	11.1	22.8*	0.85	885*	11.8*	330
Methyl Red	11.7*	11.3	23.1*	0.78	768*	12.6*	339*
Methyl Orange	13.5	11.0	24.5*	0.82	1159*	13.9	338*
Titan yellow	10.3*	11.8	26.8	0.33	1207*	15.6	330
Indigo caramine	15.5	12.8	27.8	0.86	1262	13.1*	330
Natural dye -kumkum	12.9	10.8*	23.8*	0.81	1020*	11.7*	338*
Natural dye – yellow	12.7	10.4*	23.2*	0.72	970*	11.7*	340*
Natural dye – pink	12.7	5.9*	18.6*	0.35*	711*	8.4*	339*
Natural dye – Blue	13.0	10.0*	23.0*	0.68	916*	9.8*	340*
Natural dye –Brickred	13.1	10.2*	23.3*	0.64	838*	11.9*	338*
Control	15.8	13.2	29.0	0.77	1490	15.8	329
SEd±	1.8	1.1	1.8	0.08	109.8	0.9	1.3
CD (P=0.05)	3.6	2.3	3.7	0.18	228.5	1.9	2.5

*Significant at P=0.05

Table 2 Influence of seed colouring on seed germination (%), seedling growth and vigour index in sunflower (Cv. Morden)

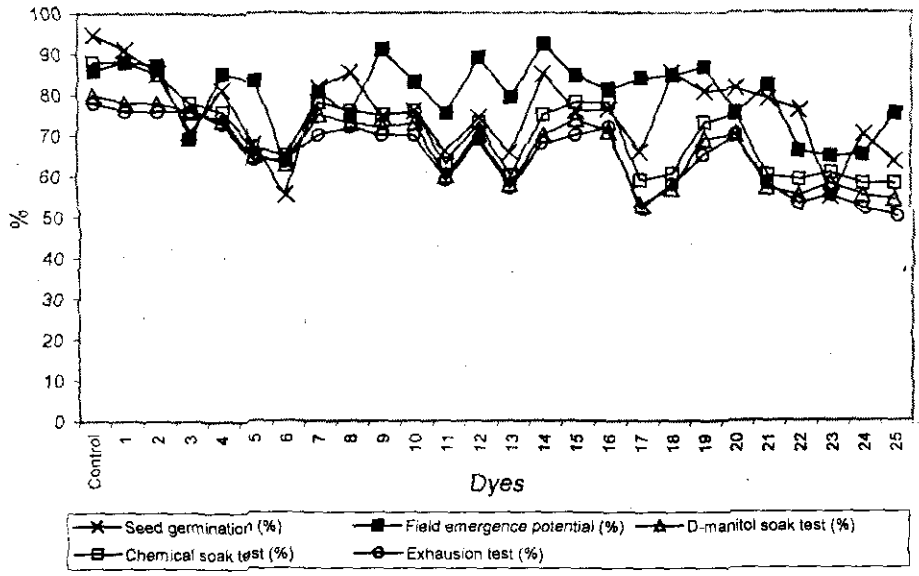
Name of the dye	Root length (cm)	Shoot length (cm)	Whole seedling length (cm)	Dry weight of seedling (g)	Vigour Index (RL x G%)	Speed of germination	EC (μ mhos/cm)
Rhodamine-B	13.4	14.2	27.7	0.13	1180	7.8*	382
Cotton Blue	11.5	14.9	26.4	0.17*	790	10.7	382
Fuchsine	11.6	13.7	25.4	0.17*	893	9.6	383
Neutral Red	12.0	14.8	16.9	0.11	815	6.3*	382
Gentian violet	14.6	14.0	28.8	0.09	904	10.9	381
Methylene Blue	12.3	14.1	26.5	0.11	862	10.7	390*
Crystal violet	14.0	14.4	28.4	0.12	767	14.2	383
Congo red	15.0	15.3	30.4	0.11	1366*	9.8	383
Fast green	13.2	16.5	29.8	0.09	989	11.8	382
Bromocresol purple	15.6*	16.0	31.6*	0.13	1260	10.3	383
Phenol Red	15.5*	16.8*	32.3*	0.11	1068	7.7*	393*
Nigrosine	16.5*	15.2	31.7*	0.14	905	12.3	382
Erichro black-T	12.7	15.1	27.9	0.05	845	10.5	395*
Mureoxide (Amm.pur)	8.2*	13.3	21.5	0.17*	485*	12.0	385
Bromocresol green	13.6	14.3	28.0	0.09	852	13.8	382
Malachite green	11.8	12.9	24.8	0.12	601*	8.0*	383
Methyl Red	11.1	16.3	27.4	0.14	613*	8.1*	393*
Methyl Orange	10.2	15.5	25.8	0.08	536*	12.3	397*
Titan yellow	11.2	13.4	24.6	0.10	954	10.8	382
Indigo caramine	14.1	15.9	30.0	0.13	1050	13.3	383
Natural dye -kumkum	13.8	12.5	26.4	0.13	898	6.9*	397*
Natural dye – yellow	13.3	12.8	26.1	0.10	655	9.9	395*
Natural dye – pink	10.9	11.5*	22.4	0.14	630	0*	395*
Natural dye – Blue	9.0	14.0	23.0	0.11	588*	0*	397*
Natural dye –Brickred	10.1	12.5	22.6	0.12	647	1.8*	398*
Control	11.8	14.2	25.9	0.10	1008	12.2	382
SEd±	1.6	1.2	2.2	0.03	146.2	1.5	2.5
CD (P=0.05)	3.3	2.5	4.5	0.05	304.1	3.1	5.0

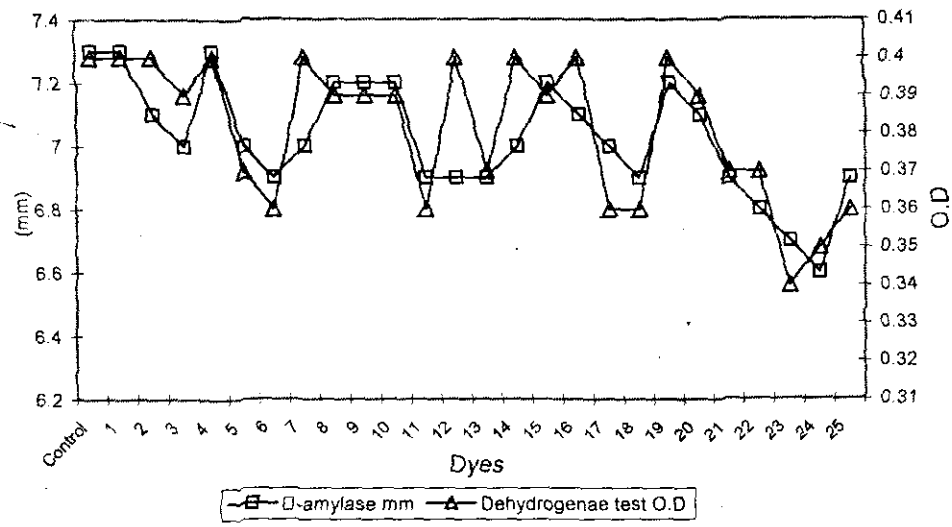
*Significant at P=0.05

Table 3 Influence of seed colouring on seed germination (%), seedling growth and vigour index in safflower (Cv. Bheema)

Name of the dye	Root length (cm)	Shoot length (cm)	Whole seedling length (cm)	Dry weight of seedling (g)	Vigour index (RL x G%)	Speed of germination	EC (μ mhos/cm)
Rhodamine-B	10.4	12.9	23.3*	0.16*	989*	16.9*	218
Cotton Blue	11.1	13.8*	25.0	0.12	822*	16.8*	220
Fuchsine	10.4	13.2	23.6*	0.13	1012*	15.2*	219
Neutral Red	12.1	13.5*	25.7	0.11	1152*	21.1	218
Gentian violet	13.3	13.3	26.6	0.09	1169*	17.7*	227*
Methylene Blue	13.1	11.3	24.4*	0.10	1121*	17.8*	229*
Crystal violet	9.3	11.1	20.5*	0.06	892*	19.0	220
Congo red	11.7	13.0	24.8*	0.13	1141*	19.4	220
Fast green	11.1	11.6	22.7*	0.12	1025*	21.2	219
Bromocresol purple	11.7	12.3	24.0*	0.10	1045*	19.1	220
Phenol Red	12.8	12.7	25.5	0.11	956*	20.3	230*
Nigrosine	14.3	13.1	27.4	0.07	934*	19.0	218
Erichro black-T	11.9	12.6	24.5*	0.07	1060*	15.5*	233*
Mureoxide (Amm.pur)	12.5	12.9	25.5	0.09	1164*	13.7*	220
Bromocresol green	11.6	13.8*	25.4	0.08	730*	15.7*	219
Malachite green	14.3	13.3	27.8	0.12	1153*	18.7	218
Methyl Red	10.0	11.0	21.0*	0.08	900*	15.6*	237*
Methyl Orange	11.7	12.3	24.0*	0.15	1059*	17.1*	240*
Titan yellow	11.8	13.1	24.9	0.06	1094*	11.3*	218
Indigo caramine	13.5	14.0*	27.5	0.10	1144*	14.2*	219
Natural dye -kumkum	19.0	10.2*	19.2*	0.14	721*	7.4*	243*
Natural dye – yellow	11.7	12.0	25.8	0.10	1048*	10.3*	244*
Natural dye – pink	10.4	12.0	22.5*	0.10	893*	8.2*	240*
Natural dye – Blue	9.5	11.3	20.8*	0.07	650*	8.2*	241*
Natural dye –Brickred	10.6	12.1	22.7*	0.11	865*	14.2*	245*
Control	15.3	12.1	27.5	0.11	1446	22.4	219
SEd±	3.0	0.6	1.2	0.02	99.2	1.7	1.8
CD (P=0.05)*	6.2	1.3	2.6	0.04	206.4	3.5	3.7

*Significant at P=0.05

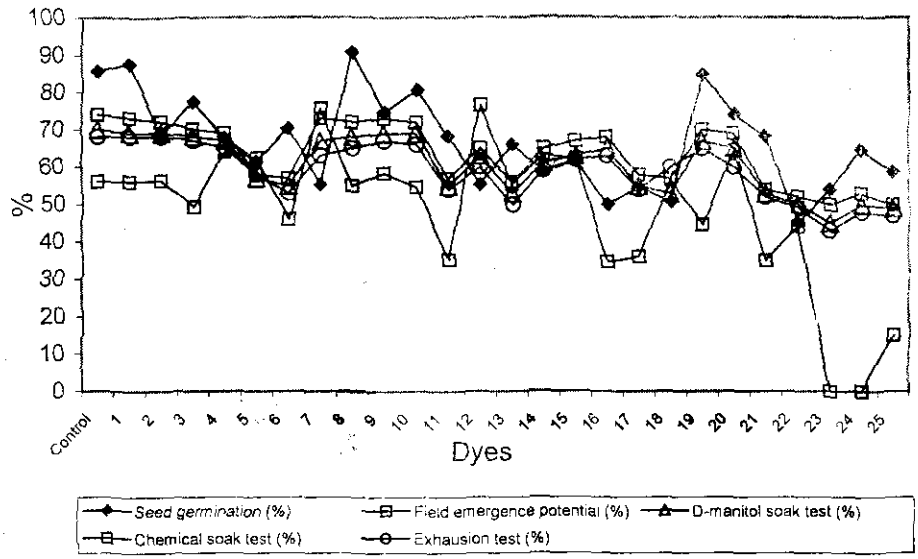


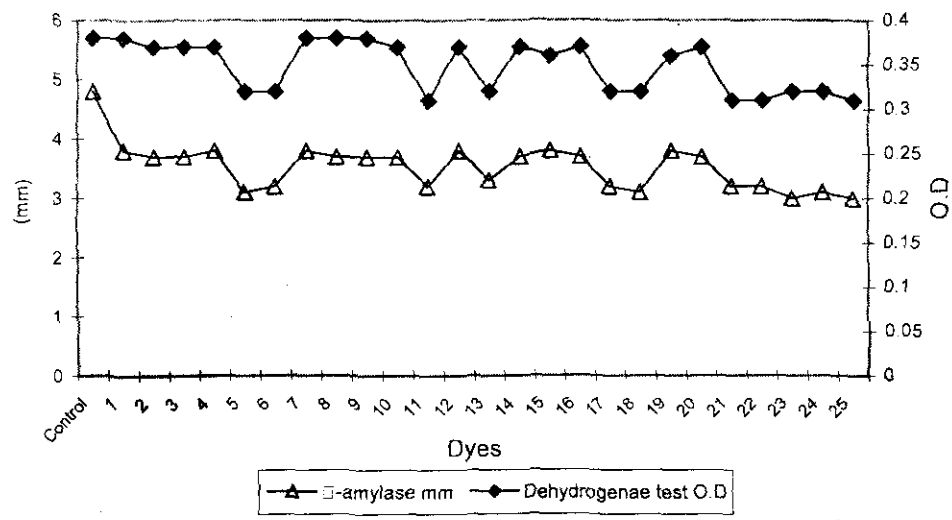


Dyes :

Control	9. Fast green	18. Methyl Orange
1. Rhodamine-B	10. Bromocresol purple	19. Titan yellow
2. Cotton Blue	11. Phenol Red	20. Indigocaramine
3. Fuchsim	12. Nigrosine	21. Natural dye-kumkum
4. Neutral Red	13. Erichroblack-T	22. Natural dye – yellow
5. Gentian violet	14. Mureoxide (Amm.pur)	23. Natural dye – pink
6. Methylene Blue	15. Bromocresol green	24. Natural dye – Blue
7. Crystal violet	16. Malachite green	25. Natural dye –Brickred
8. Congo red	17. Methyl Red	

Fig.1: Influence of seed colouring on germination potential, field emergence and enzyme activity in castor (PCS - 4)

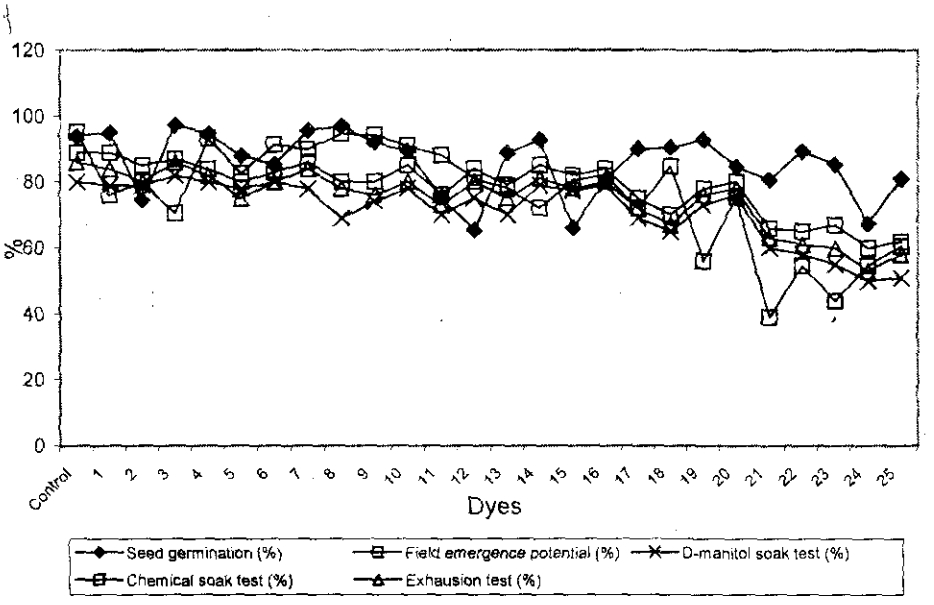


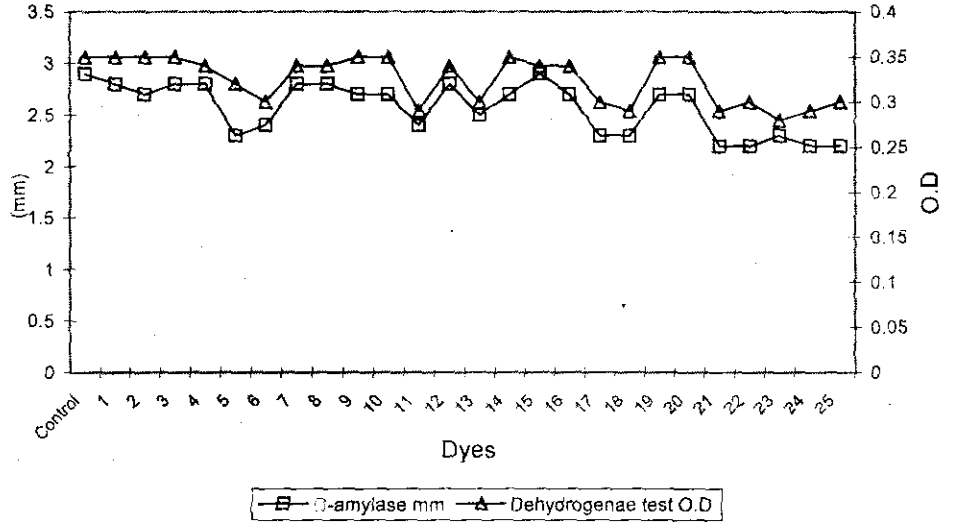


Dyes :

Control	9. *Fast green*	18. Methyl Orange
1. Rhodamine-B	10. Bromocresol purple	19. Titan yellow
2. *Cotton Blue*	11. *Phenol Red*	20. *Indigocaramine*
3. Fuchsim	12. Nigrosine	21. Natural dye-kumkum
4. *Neutral Red*	13. *Erichroblack-T*	22. *Natural dye – yellow*
5. Gentian violet	14. Mureoxide (Amm pur)	23. Natural dye – pink
6. *Methylene Blue*	15. *Bromocresol green*	24. *Natural dye – Blue*
7. Crystal violet	16. Malachite green	25. Natural dye –Brickred
8. *Congo red*	17. *Methyl Red*	

Fig.2 : Influence of seed colouring on germination potential, field emergence and enzyme activity in sunflower (morden)





Dyes : Control

1. Rhodamine-B
2. Cotton Blue
3. Fuchsim
4. Neutral Red
5. Gentian violet
6. Methylene Blue
7. Crystal violet
8. Congo red
9. Fast green
10. Bromocresol purple
11. Phenol Red
12. Nigrosine
13. Erichroblack-T
14. Mureoxide (Amm.pur)
15. Bromocresol green
16. Malachite green
17. Methyl Red
18. Methyl Orange
19. Titan yellow
20. Indigocaramine
21. Natural dye-kumkum
22. Natural dye – yellow
23. Natural dye – pink
24. Natural dye – Blue
25. Natural dye –Brickred

Fig.3 : Influence of seed colouring on germination potential, field emergence and enzyme activity in safflower (*Bheema*)

Through this study on colour standards, we would like to propose for efforts to standardize reproducible colour standards for crops as in USA, Canada and Europe. We propose that this provision can also be incorporated under the regulations of seed quality and pest control act after suitable modifications in the text that " Where the physical properties of the control product are such that the presence of the control product may not be recognized when used and is likely to expose a person or domestic animal to severe health risk, the control product shall therefore be denaturized by means of colour, odour or such other means as the central seed committee may approve to provide a signal or warning as to its presence".

When the coloured seed is packed, the package should bear a label with words " the seed is treated and coloured with" followed by the name of the control measure product and the seed colouring dye, including the common name or chemical name of its active ingredient together with appropriate precautionary symbol and signal or warning words as the Central Seed Committee or National Seed Board may approve.

If the treated-coloured seed is sold and shipped or exported in bulk, the shipping documents should bear information containing the common name or chemical name of active ingredient of both chemical and the seed colouring dye with a sub note that "seed colouring dye used is not injurious to seed".

This will enable seed industry to adopt individual colours as their trademark including propriety colouring of parental lines to identify their seeds. The seed colouring will substantially aid in preventing accidental usage of treated seeds as food or feed, or may help in upgrading the visual quality of blonded (discoloured and rain soaked) and blended seeds (but, still maintaining seed germination above seed certification standards under emergent situations where there is scarcity of seeds.

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Rheological properties of NSFH-36 sunflower seed as a function of moisture content and their effect on dehulling of seed

R.K. Gupta and M.R. Manikantan

Central Institute of Post-Harvest Engineering and Technology, Ludhiana-141 004, Punjab

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Abstract

The investigation was carried out to generate basic data on various rheological properties of sunflower seed and its kernel as a function of moisture content and their effect has been co-related for optimization of dehulling performance of hand operated sunflower decorticator. The rheological parameters *viz.*, initial cracking force (ICF), average rupture force (ARF) and rupture energy (RE) were measured by Texture Analyzer and analyzed for at least three replications between the moisture content of 6 to 14% db. All the rheological properties were found in decreasing trend with increase in moisture content between 6.0 to 14% db. Hand operated decorticator was modified for dehulling of sunflower seeds. Coarse emery paper of grade B, No. 50 was pasted on its oscillating shoe made of wood and screen of 2.5 x 20 mm was found in giving better results. Effect of moisture content of seeds was studied on dehulling performance using the above decorticator and it revealed that the maximum dehulling efficiency of 73% was obtained when graded sunflower seeds (retain above 3 x 20mm sieve) having moisture content of 8% db. In this moisture range the rate of reduction in initial cracking force, rupture force and energy were also more, which might have resulted more dehulling efficiency.

Key words: Sunflower, rheological properties, moisture content, dehulling, decorticator

Introduction

To meet the growing demand of edible oils in the country, it has become necessary to not only augment the resources for production of more oilseeds but also conserve the oilseeds and its by-products through suitable processing techniques. Production of sunflower oil is being practiced in India mostly (about 80%) through solvent extraction and about 20% is being crushed in screw expeller leaving significant quantity of residual oil in the meal. The presence of fairly high proportion of hull in the sunflower seed not only causes rapid wear of the moving parts of the expeller but reduces the total oil yield showing consumption of high specific energy and yielding cake of no use. Meal which contains husk in significant quantity is used as manure or thrown as such while this meal is containing 36% protein and could be used for various protein enriched food products preparation at lower cost. The sunflower seed contains protein in the range of 24-27% whereas kernel contains as high as 36% protein and could be used for various protein enriched food products preparation at lower cost (Earle *et al.*, 1986; Lanfranco *et al.*, 1989). Sunflower kernel and its defatted meal have some advantages over other oilseeds meal as human protein food because of their flavor, high digestibility, biological value and absence of anti-nutritional or toxic factors (Clandinin, 1978). Tranchino *et al.* (1984) reported that sunflower kernel is also a good source of vitamin, calcium, iron and phosphorus. Many researchers have also advocated for incorporation of either defatted flour or roasted sunflower grits as protein enrichment of bakery products (Rooney *et al.*, 1982; Talley *et al.*, 1982; Leelavathi *et al.*, 1991).

Also, during extraction of oil from sunflower seed either by mechanical expression or through solvent extraction, pigments present in the hull are transferred to the extracted oil resulting dull coloured sunflower oil which is being removed during refining causing increased refining cost. If hull could be removed prior to extraction, refining cost would be lower and good quality oil could be produced at reduced processing cost. Extraction of oil using dehulled seed may also reduce the volume of solvent being used for extraction of oil. This may benefit oil industry to a tune of million of rupees. Mechanical expression of partially dehulled sunflower seeds is being sought in some developed countries to overcome these drawbacks (Subramanian *et al.*, 1990). Isobe *et al.*, (1992) in the laboratory trial with twin-screw press have reported recovery of 93.6% of the kernel oil by mechanical expression of dehulled sunflower seed.

Some physical properties of this seed and kernel and their comparison with other seeds are considered to be necessary for the proper design of equipment for handling, conveying, separation, dehulling, drying, mechanical expression of oil, storage and other processes (Shukla *et al.*, 1992). The present study was aimed to generate

information on some rheological properties of sunflower seed and its kernel as a function of moisture content and their effect has been studied on dehulling of sunflower seed.

Material and methods

The sunflower (Hybrid, NSFH-36) grown at CIPHET farm during the years 2003 and 2004 was used for the present study. The seeds were cleaned in CIAE cleaner and grader using appropriate set of sieves to remove foreign matter, broken and immature seeds and grading of seeds followed. The seeds retain above 3 x 20 mm sieve were used for the study. The initial moisture content of the seeds was measured by hot air oven method. The oil content was determined using Soxhlet apparatus. To obtain whole kernels, the seeds were manually dehulled. Both seeds and kernels were packed separately in double-layered low-density polyethylene bags of 90µm thickness, sealed and stored at low temperature (277° K). All Rheological properties were determined between the moisture content of 6.0 to 14% db with three replications. The ANOVA test was also carried out to see the variation in rheological properties with moisture content.

The hardness and rupture force was measured using Texture Analyzer (Model TA-Hdi). Stable Micro systems Texture Analyzers are designed and manufactured for long-term reliability and accuracy. For high force applications, the TA-HDi 'Heavy Duty' has force capacities of 50, 100, 250 and 500 kg and test range of 774 mm. This instrument is ideal for tension, compression tests on food, pharmaceutical, chemical and allied products.

The overall performance of the TA-HDi is enhanced by the addition of Texture Expert Exceed, a Microsoft Windows compatible data acquisition, display and management software package which is totally dedicated to texture analysis. A family of flat-ended probes from 2 mm to 50 mm diameter is available to test a wide range of samples. For testing sunflower seeds, 5 mm diameter stainless steel probe (P/5) was used.

The TA measures force, distance and time, thus providing three dimensional product analysis. Distance and speed control is achieved using a stepping motor attached to a fine lead screw that winds the probe carrier up and down. An accurate quartz crystal clock achieves timing. The probe carrier contains a very sensitive load cell. With each of the load cell capacities the actual measuring range is split such that the full range is available in the selected mode, and a further 10% of full scale in the 'negative direction'. The load cell has mechanical over load and under load protection and an electronic monitoring system that stops the motor drive when an overload condition is detached.

The condition-set up in the TA for measuring Rheological properties is given below:

Pre-test speed : 1.5 mm/sec; Test speed : 0.5 mm/sec; Post-test speed : 10 mm/sec; Test Distance : 3 mm for oilseed and 1.5 mm for kernel, Trigger type : Auto; Trigger force : 0.20 N; Break detect : Return; Break sensitivity: 0.15 N; Acquisition rate: 200 PPS; Load cell : 50 kg and Probe : P/5.

(N.B.: The test distance was selected according to the thickness of seed and kernel)

The seed/kernel was placed over the central point of the test base under the probe in TA. During the RUN mode, after attaining the trigger force of 0.20 N, the TA operation was started. After attaining the test distance, TA returned to the original position. During the TEST mode, the graph was drawn between the force resisted by the test material and distance.

From the graph, the initial peak position was considered as initial cracking of the test material. Hence, the force related to this initial peak position was considered as initial cracking force. The average force experienced by the test material from zero to the test distance is considered as average rupture force and the area under this curve is known as rupture energy. Initial cracking force could be responsible for decortication and rupture force and rupture energy could be contributed towards the oil expulsion.

The hand operated decorticator was modified for dehulling of sunflower seeds. Coarse emery paper of grade B, No.50 was pasted on its oscillating shoe made of wood and screen of 2.5x20mm was used as a rubbing surface. Effect of moisture content of seeds between the moisture content of 6.0 to 14% db. was studied on dehulling performance using the above decorticator. The principle involved in the decortication process is the combined action of friction and shear. The decortication efficiency was calculated as follows. Three replication were done for all the experiments and average values are reported.

Decortication efficiency (%) =

$$\frac{\text{Weight of decorticated seed (kernel)}}{\text{Mean kernel fraction of input seed}} \times 100$$

Results and discussion

Rheological properties of sunflower seed and kernel: It was observed that initial cracking force, average rupture force and rupture energy for both seeds and kernels were in decreasing trend with increase in moisture content (Fig. 1 and 2). The rate of decrease in absorption of moisture may be attributed to the softening of the cells and decrease in cracking and rupture force. The differences in rheological properties for sunflower seed as well as kernel with moisture content was found statistically significant (Table 1 and 2). From Fig. 1 it could be seen that between 7-8% moisture content (db), there is steep decrease in the rupture force was noticed for sunflower seed.

Table 1 Analysis of variance test for sunflower seed to examine the significance level for variation in rheological properties with moisture content

Source		Sum of squares	df	Mean square	F_{cal}	Significance
ICF (N)	Between groups	3024.7	4	756.1	3.9	0.017*
	Within groups	3860.3	20	193.0		
	Total	6885.1	24			
ARF (N)	Between groups	18069.8	4	4517.4	20.5	0.012*
	Within groups	4397.1	20	219.8		
	Total	22466.9	24			
RE (N-mm)	Between groups	257371.9	4	64342.9	27.5	0.017*
	Within groups	46760.0	20	2338.0		
	Total	304132.0	24			

ICF (N) = Initial cracking force of sunflower seed, Newton; ARF (N) = Initial rupture force of sunflower seed, Newton
RE (N-mm) = Rupture energy of sunflower seed, Newton-millimeter * = Significant at 5% level

Table 2 Analysis of variance test for sunflower kernel to examine the significance level for variation in rheological properties with moisture content

Source		Sum of squares	df	Mean square	F_{cal}	Significance
ICF (N)	Between groups	1645.7	5	329.1	3.5	0.015*
	Within groups	2231.6	24	92.9		
	Total	3877.3	29			
ARF (N)	Between groups	1617.8	5	323.5	3.4	0.016*
	Within groups	2224.7	24	92.6		
	Total	3842.6	29			
RE (N-mm)	Between groups	3899.7	5	779.9	3.6	0.014*
	Within groups	5190.2	24	216.2		
	Total	9089.9	29			

ICF (N) = Initial cracking force of sunflower seed, Newton; ARF (N) = Initial rupture force of sunflower seed, Newton
RE (N-mm) = Rupture energy of sunflower seed, Newton-millimeter * = Significant at 5% level

Dehulling efficiency: The dehulling efficiency of hand operated decorticator for sunflower seeds was evaluated for the moisture content between 6-14%(db) and shown in Fig.3. Effect of moisture content of seeds was studied on dehulling performance using the above decorticator and study revealed that better dehulling efficiency could be achieved if sunflower seed has moisture content in the range of 7 to 8%db. The maximum dehulling efficiency of 73% was obtained when graded sunflower seeds (retain above 3x20mm sieve) having moisture content of 8% db were dehulled in the above decorticator. In this moisture range the rate of reduction in rupture force (Fig. 1) for sunflower seed was also more, which might have resulted more dehulling efficiency.

The dehulling efficiency was increased for the sunflower seeds having moisture content up to 8% db and then it was decreased as the percent of moisture increased. The decrease in dehulling efficiency may be attributed to the decrease in shear and frictional force due to increase in moisture content of sunflower seeds.

Fig. 1 Rheological properties of sunflower oilseed

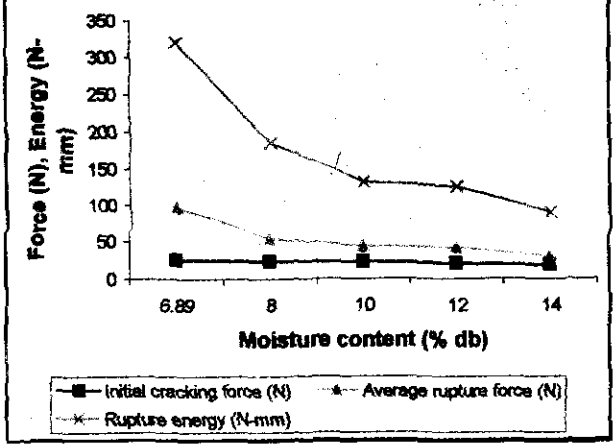


Fig. 2 Rheological properties of sunflower kernel

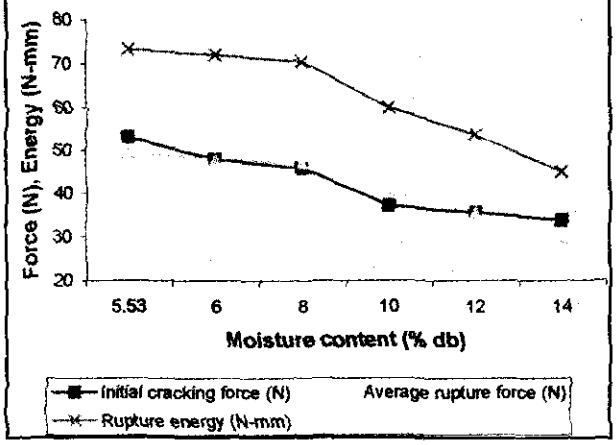
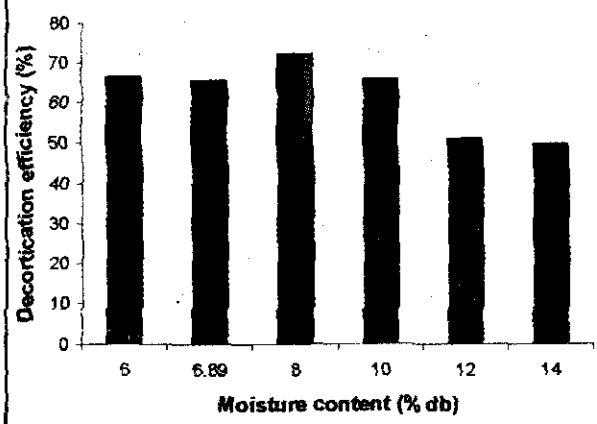


Fig. 3 Effect of moisture on dehulling efficiency



Conclusions

The rheological properties namely initial cracking force, average rupture force, rupture energy were in decreasing trend with increase in moisture content between 6.0 to 14% db.

The initial cracking force was more as compared to average rupture force for sunflower seed and its kernel.

More energy was required to rupture the sunflower seed as compared to kernel.

The dehulling efficiency was increased for the sunflower seeds having moisture content up to 8% db and then it was decreased.

The maximum decortication efficiency of 72.23% was obtained for the sunflower seeds having moisture content 8% (db).

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Short communication

Performance of single cross hybrids in sunflower, *Helianthus annuus* L.

B. Narendra and G. Appa Rao

Regional Agricultural Research Station, ANG Ranga Agril. University, Nandyal, AP

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A spectrum of varieties with different duration and yield potential of sunflower are available for cultivation in India. The first commercial Sunflower hybrid developed by exploitation of heterosis with the use of cytoplasmic male sterile (cms) system in USA during 1972 heralded its diffusion to all parts of the world. Based on this success, the Indian scientists released the first Sunflower hybrid, BSH-1 in 1980. Later on several hybrids both from public sector and private sector plunged in to the cultivation. Apart from its high yielding ability, it has several desirable attributes like drought tolerance, early maturity and resistance to biotic and abiotic stresses. In sunflower improvement through different angles, it is essential to synthesize and evaluate new hybrids. Therefore, as a mandate research activity, efforts were made to evaluate newly developed single cross hybrids.

During *Rabi*, 2002 crossing programme was initiated involving 10 CMS lines and 39 restorer lines in different combinations. Thirty four new hybrids were developed and evaluated with NDSH-1, a new hybrid as check in Randomized Block Design with two replications in a plot size of 3 m X 4.5 m length during *kharif*, 2003 at RARS, Nandyal (Table 1).

The differences among the new two way hybrids found were highly significant for plant height, head diameter and seed yield indicating that there is a considerable variability which can be exploited for the development of hybrids with high yield (Table 1). Only three hybrids, NDSH-595, 596 and 613 recorded significantly higher yields than check, NDSH-1. Regarding head diameter, all the new hybrids are on par with the check, NDSH-1 except NDSH-598, 616,617 and 623 recording exceedingly low head size explaining the reason for their low yielding potential. It is also observed in case of NDSH-599, 608, and NDSH-620 that inspite of less 100 seed weight, if the head size is average then also those hybrids recorded good yield. Hence, it can be concluded that head diameter is highly capable of influencing the yield potential to a great extent in sunflower. These results are in consonance with those reported by Parameshwari *et al.*, (2004). Regarding days to 50% flowering, none of the hybrids was found to mature earlier than the check indicating lack of variability among the parents for this character.

Table 1 Evaluation of single cross hybrids in sunflower

Hybrid	Plant height (cm)	Head Diameter (cm)	100 seed weight (g)	Days to 50% flowering	Seed Yield (Kg/ha)
NDSH-595	82	15	3.9	51	1390
NDSH-596	84	12	4.9	49	1500
NDSH-597	81	12	4.4	48	1220
NDSH-598	80	9	1.4	50	1050
NDSH-599	84	11	2.7	51	1280
NDSH-600	84	13	3.7	57	1220
NDSH-601	78	10	3.3	53	1300
NDSH-602	99	11	3.0	54	1290
NDSH-603	100	12	3.7	58	1310
NDSH-604	88	12	3.3	51	1350
NDSH-605	103	15	3.4	49	1320
NDSH-606	88	10	3.8	58	1300
NDSH-607	77	11	3.3	53	1260
NDSH-608	80	10	2.8	49	1230
NDSH-609	95	12	3.3	52	1230
NDSH-610	80	11	3.5	48	1210
NDSH-611	82	11	4.4	49	1250
NDSH-612	98	14	4.0	50	1290
NDSH-613	97	12	4.3	49	1420
NDSH-614	84	11	3.0	51	1220
NDSH-615	86	10	3.1	58	1210
NDSH-616	59	9	2.6	49	1140
NDSH-617	92	9	2.5	51	1150
NDSH-618	85	11	3.0	53	1150
NDSH-619	98	13	4.5	58	1330
NDSH-620	74	11	2.3	58	1260
NDSH-621	76	11	3.4	48	1190
NDSH-622	88	12	3.5	49	1300
NDSH-623	78	9	2.8	48	1110
NDSH-624	78	10	3.0	53	1300
NDSH-625	104	13	4.2	55	1310
NDSH-626	92	12	3.8	59	1340
NDSH-627	93	11	4.3	54	1270
NDSH-628	90	15	4.5	58	1195
NDSH-1 ©	103	13	5.2	48	1260
Grand Mean	87	11	3.6	52	1255
C.V (%)	13.37	14.4	20.4	2.7	4.7
CD (P=0.05)	22.80	3.3	1.4	2.8	120
SEm±	8.15	1.2	0.52	1.00	0.4

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Short communication

Combining ability studies for seed yield and yield contributing characters in sunflower, *Helianthus annuus* L.

B.V. Vara Prasad, A. Vishnuvardhan Reddy* and T. Nageswara Rao

Department of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad-500 030, AP

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Sunflower, *Helianthus annuus* L. is one of the most important oilseed crops of India. It is a crop in which heterosis is exploited for better seed yield and oil. Availability of cytoplasmic male sterility and fertility restoring source, and highly cross pollinating nature of sunflower has made the exploitation of heterosis possible on commercial scale. Hybrids are generally more vigorous, uniform, self-fertile and resistant to many pests and diseases. So, it is essential to identify superior parents for hybridization programme. Combining ability analysis helps in the identification of suitable parents for further exploitation in breeding programmes. This study also assess the gene action governing the different characters which help the breeder to understand the inheritance and enables him for further improvement of the crop.

Four CMS and 15 restorer lines were crossed in L x T fashion to generate 60 single cross hybrids during *kharif*, 2002 at Directorate of Oilseeds Research, Hyderabad. The hybrids obtained were sown along with their parents in Randomized Block Design in three replications giving a spacing of 60 x 30 cm during *rabi*, 2002-03 at Directorate of Oilseeds Research, Hyderabad. Recommended package of practices were adopted to raise a healthy crop and regular plant protection measures were taken. Data were recorded on five randomly selected plants in each entry and in each replication for nine quantitative characters *viz.*, plant height, days to 50% flowering, days to maturity, head diameter (cm), number of filled seeds/plant, filled seed (%), 100-seed weight, seed yield/plant (g) and oil content (%). Combining ability analysis was carried out following the model proposed by Kempthorne (1957) to estimate *gca* and *sca* effects and variances.

Analysis of variance for combining ability indicated that the mean sum of squares due to genotypes, parents, parents vs. crosses, crosses and line x tester exhibited significant differences for all the nine characters studied, while the lines were found significant for plant height and testers for filled seed (%).

Genetically *gca* is associated with genes which are additive in nature, while *sca* is primarily due to dominance and epistasis. In the present study, the ratio of *gca* to *sca* variances showed the preponderance of non-additive type of gene action for all the yield and yield contributing characters. These results are corroborated with the findings of Sheriff *et al.* (1985); Govindaraju *et al.* (1992); Gangappa *et al.* (1997); Lande *et al.* (1997) and Radhika *et al.* (2001).

Among the male parents, the high *gca* effects in desirable direction for earliness and dwarfness was recorded by the Line DSI-219 and it was DCMS-23 among the females, indicating that they are good general combiners for earliness and plant height (Table 1).

Among the female lines, DSI-216 was found good general combiner for head diameter and seed yield/plant. The inbred line DSI-207 was a good combiner for head diameter, number of filled seeds/plant and seed yield/plant. The female CMS line DCMS-14 and the male parent DSI-204, were superior for 100-seed weight.

A significant *gca* effect for oil content was recorded by the tester DSI-220 and at the other hand it was found to be poor combiner for seed yield. The parent DSI-207 was found good general combiner for most of the yield and yield contributing characters. The superior combining ability effects reveal the best cross combinations among the genotypes which can be useful for generating hybrids having high vigour for traits and significant *sca* effects were observed for all the traits studied (Table 2).

The cross combinations, DCMS-23 x DSI-180; DCMS-23 x DSI-28; DCMS-14 x DSI-206 and DCMS-14 x DSI-220 were found to be the best specific combiners for most of the yield and yield contributing characters. The hybrids DCMS-18 x DSI-216; DCMS-14 x DSI-225; DCMS-5 x DSI-180 and DCMS-18 x DSI-204 were proved to be good combiners for seed yield/plant with 48.30; 46.80; 46.15 and 45.16 g of per se performance, respectively, and the cross combinations, DCMS-23 x DSI-180; DCMS-18 x DSI-218; DCMS-23 x DSI-224 and DCMS-5 x DSI-216 were found

* Senior Scientist (Plant Breeding), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, A.P.

as good specific combiners for oil content and recorded 46.60, 43.13, 42.27 and 38.30% of oil, respectively. The hybrids, DCMS-14 x DSI-220; DCMS-23 x DSI-180; DCMS-23 x DSI-208 and DCMS-14 x DSI-225 were found good combiners for both seed yield (40.41, 31.27, 30.12 and 28.08 g, respectively) and oil content (41.60, 46.60, 37.80 and 36.63%, respectively).

Table 1 Estimates of general combining ability effects for lines and testers for nine traits in sunflower

Parent	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	No. of filled seeds/plant	Filled seeds (%)	100 seed weight (g)	Seed yield/ plant	Oil content (%)
Line									
DSI-202	0.64	1.4092*	-17.18**	-0.4625	-57.4556	0.10	-0.10	-3.17	0.24
DSI-82	-0.94	-0.42	2.60	-0.06	-108.5389*	-3.50	-0.06	-5.9733**	0.28
DSI-180	0.22	-0.17	-0.63	-0.7675*	8.63	-1.22	0.04	0.86	2.84
DSI-181	0.22	0.25	4.54	-0.43	-82.2889	-1.88	0.06	-4.0349*	-1.46
DSI-204	0.22	0.00	5.05	0.26	68.46	0.72	0.5256*	6.0551**	-0.91
DSI-206	-0.94	-0.67	-0.91	0.46	69.13	0.87	0.34	4.8526**	-3.5728*
DSI-207	2.4722**	1.7442**	10.6497*	0.7550*	154.1278**	5.13	0.39	9.6242**	-4.4811**
DSI-208	0.14	0.74	-7.26	-0.7950*	18.29	2.67	-0.05	-0.11	2.74
DSI-212	0.31	-0.01	17.1413**	0.65	5.63	3.44	0.00	-0.25	-4.0061*
DSI-218	0.56	1.08	2.53	-0.03	22.13	-3.16	-0.14	0.98	1.89
DSI-216	0.72	-0.17	13.8663**	1.0600**	68.13	5.22	0.03	3.5409*	-3.3061*
DSI-219	-1.7778*	-1.5883*	-11.90*	-0.21	-22.4556	-9.2862**	-0.49*	-3.7174*	2.32
DSI-220	-1.19	-1.17	-5.00	-0.09	-77.2889	-2.38	-0.5711**	-6.2258**	6.8439**
DSI-224	-1.53	-1.4233*	-11.20*	-0.8425*	-128.3722*	-2.61	-0.10	-6.5349**	1.46
DSI-225	0.89	0.41	-2.30	0.50	61.88	5.8913*	0.13	4.1109*	-0.86
SEi	0.22	0.16	1.24	0.09	11.75	0.74	0.05	0.41	0.39
Tester									
DCMS-14	-0.5500	-0.7058**	4.3458*	-0.1885	1.2722	-1.2019	0.1677*	1.0049	-0.5500
DCMS-18	0.9611**	0.5608*	-2.4507	0.2295	17.5833	1.5216	-0.1449	0.1456	0.9700
DCMS-5	0.4056	0.6502*	-1.7409	-0.0212	-2.6167	-0.7311	-0.1367	-0.8999	0.3233
DCMS-23	-0.8167*	-0.5052*	-0.1542	-0.0198	-16.2389	0.4114	0.1139	-0.2506	-0.7433
SEj	*0.11*	*0.08*	*0.64*	*0.04*	*6.06*	*0.38*	*0.02*	*0.21*	*0.20*

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

Table 2 Estimation of specific combining ability for nine characters studied in sunflower

Cross	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	No. of filled seeds/plant	Filled seeds (%)	100 seed weight (g)	Seed yield/ plant (g)	Oil content (%)
DCMS-18 x DSI-204	-1.04*	-0.39	1.24	1.31**	174.25**	-3.16*	0.28**	10.78**	0.20
DCMS-18 x DSI-218	-1.04*	-2.15**	-0.44	0.10	32.92	4.17**	-0.54**	-3.95**	10.10**
DCMS-18 x DSI-216	2.12**	3.11**	7.56**	1.27**	213.25**	1.87	0.91**	16.43**	-5.41**
DCMS-23 x DSI-180	-3.27**	-2.50**	3.99	2.04**	49.57*	-7.97**	0.08	2.48**	11.33**
DCMS-23 x DSI-208	0.15	-1.07**	20.74**	1.40**	62.57**	-1.59	-0.10	2.31**	2.63**
DCMS-23 x DSI-224	-0.18	1.09**	6.86**	-0.08	-71.09**	6.07**	0.01	-3.94**	8.37**
DCMS-14 x DSI-220	4.55**	4.37**	7.83**	1.70**	377.64**	10.40**	0.29**	17.45**	2.12**
DCMS-14 x DSI-225	1.47**	1.79**	-4.57	1.41**	191.81**	1.39	0.52**	13.51**	1.66*
DCMS-5 x DSI-180	2.18**	3.68**	0.37	0.57**	268.28**	9.28**	0.84**	18.01**	-6.91*
DCMS-5 x DSI-216	2.01**	0.69*	-2.95	0.50**	-124.22**	-7.38**	-0.87**	-11.53**	8.10**
SEj	0.44	0.32	2.49	0.18	23.50	1.48	0.10	0.83	0.78

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

The hybrids with significant *sca* effects in the desired direction involved parents with either high x high, a high x low, a low x low *gca* effects indicating high performance of these crosses due to additive, dominance and epistatic gene interactions, respectively.

The results of the study suggests that the ideal cross combination to be exploited is one where high magnitude of *sca* is present in addition to high *gca* in both or at least in one of the parents to produce good hybrids and as well as to exploit the heterosis in sunflower. Sindagi *et al.* (1979) also reported similar results.

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Short communication

Path analysis under different environments in castor, *Ricinus communis* L.

P. Manivel and N. Manivannan[1]

Central Potato Research Institute, Shimla-171 001, H.P.

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India is one of the major contributors in the production and trade of castor bean (*Ricinus communis* L.). Castor seed yield being a complex character is dependent on a number of characters. The information on association of yield components enables breeders to manipulate the expression of these traits for crop improvement. In castor most of the characters are governed by quantitative genes which are influenced by environment and the entire success or failure of a breeder to achieve his goal depends on to what extent the environment modifies the gene action. The precision of selection becomes lesser and lesser with increase in environmental effects. In order to obtain accurate results the genotypes have to be evaluated over multilocations/seasons (Patil and Jaimini, 1988). Hence, the present investigation was designed to determine the components of yield in castor under four environments (two different seasons and locations).

The experiments were conducted at Oilseeds Research Station, Tindivanam and Sugarcane Research Station, Cuddalore. A total of 79 genotypes comprising of four pistillate female lines, 15 male inbreds and their 60 hybrids (derived from L x T design) were evaluated in Randomized Block Design with three replications in two seasons namely summer 1992 (irrigated) and *kharif*, 1993 (rainfed) at the above mentioned two locations. These environments were chosen to assess the influence of rainfed and irrigated situations under red and clay loam soil on association of characters. Each entry was planted in two rows each accommodating 10 plants with a spacing of 90 cm x 45 cm. Normal agronomic practices were followed throughout the crop growth. Biometrical observations were recorded on ten competitive plants for 12 characters (Table 1). The phenotypic correlation and path coefficient analysis of eleven characters on seed yield were estimated (Dewey and Lu, 1959). Data on each environment were subjected to the analysis separately.

The phenotypic correlation coefficients between the yield and yield components (Table 1) revealed that number of first order branches/plant, number of second order branches/plant, effective length of primary spike, number of spikes/plant, number of capsules/plant and 100 seed weight had significant positive association with seed yield in all the four environments indicating their direct role as yield component characters. Previous reports indicated that seed yield/plant showed significant positive association with the first and second order branches/ plant and capsules/spike (Bhatt and Reddy, 1981). Considering the interrelationship among the yield components, days to 50 % flowering had positive and significant association with plant height, number of nodes up to primary spike and 100 seed weight in all the environments and negative association with number of spikes/plant in three environments. Similarly, plant height had significant and positive association with nodes up to primary spike in all the four environments and with 100 seed weight and oil content in three environments. However, plant height had negative association with number of first order branches/plant, effective length of primary spike, number of capsules/primary spike, number of spikes/plant and number of capsules/plant in most of the environments.

Number of nodes up to primary spike had positive association with 100 seed weight in all environments; number of first order branches/plant had positive association with number of second order branches, effective length of primary spike, number of spikes/plant and number of capsules/plant in most of the environments. Number of second order branches/plant had positive association in all the four environments with number of capsules/primary spike, number of spikes/plant and number of capsules/plant. Effective length of primary spike had positive association with number of capsules/ primary spike, number of spikes/plant and number of nodes up to primary spike in three environments. Number of capsules/primary spike had positive association with effective length of primary spike, number of spikes/plant and number of capsules/plant in most of the environments. In general, plant height had negative association with most of the yield components and yield. Singh *et al.* (1981) reported that 100 seed weight had positive association with oil content. However, in the present study, 100 seed weight was positively associated with oil content in one environment only.

[1] Department of Oilseeds, Tamil Nadu Agricultural University, Coimbatore-641 003, TN.

As the correlation coefficients are insufficient to explain true relationship for an effective manipulation of the characters, path coefficients were worked out. The path analysis furnishes a method for portioning the correlation coefficients into direct and indirect effects and measures the relative importance of the casual effect factors involved (Dewey and Lu, 1959). The direct effects and total correlation of the individual characters on seed yield are presented in Table 2.

Table 1 Phenotypic correlation coefficients among characters in castor

	E@	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1 Days to 50% flowering	E_1	1.00											
	E_2	1.00											
	E_3	1.00											
	E_4	1.00											
X_2 Plant height	E_1	0.73**	1.00										
	E_2	0.37**	1.00										
	E_3	0.43**	1.00										
	E_4	0.54**	1.00										
X_3 No. Of nodes upto primary spike	E_1	0.90**	0.65**	1.00									
	E_2	0.93**	0.41**	1.00									
	E_3	0.94**	0.42**	1.00									
	E_4	0.92**	0.53**	1.00									
X_4 No. Of first order branches/plant	E_1	-0.19**	-0.30**	-0.25	1.00								
	E_2	-0.03	-0.12	-0.02	1.00								
	E_3	-0.05	-0.25**	0.03	1.00								
	E_4	-0.10	-0.26**	-0.03	1.00								
X_5 No. of second order branches/plant	E_1	-0.18**	-0.08	-0.19**	0.30**	1.00							
	E_2	-0.16**	-0.34**	-0.15**	0.07	1.00							
	E_3	0.03	-0.09	0.09	0.44**	1.00							
	E_4	-0.02	-0.23**	0.00	0.64**	1.00							
X_6 Effective length of primary spike	E_1	0.07	-0.09	0.03	0.16*	0.10	1.00						
	E_2	0.06	-0.27**	0.07	0.06	0.03	1.00						
	E_3	-0.07	-0.43**	-0.04	0.17*	0.24**	1.00						
	E_4	-0.24**	-0.48**	-0.19**	0.31**	0.35**	1.00						
X_7 No. of capsules/primary spike	E_1	0.02	-0.15*	0.02	0.14*	0.24**	0.59**	1.00					
	E_2	0.16*	-0.38**	0.10	0.10	0.25**	0.53**	1.00					
	E_3	-0.04	-0.24**	-0.03	0.03	0.17*	0.62**	1.00					
	E_4	0.04	-0.02	0.03	0.03	0.06	0.11	1.00					
X_8 No. of spikes/plant	E_1	-0.24**	-0.23**	-0.26**	0.42**	0.69**	0.22**	0.36**	1.00				
	E_2	-0.22**	-0.42**	-0.21**	0.17*	0.73**	0.24**	0.35**	1.00				
	E_3	-0.04	-0.27**	0.04	0.47**	0.72**	0.37**	0.35**	1.00				
	E_4	-0.14*	-0.35**	-0.12	0.53**	0.79**	0.43**	0.11	1.00				
X_9 No. of capsules/plant	E_1	0.04	-0.10	0.03	0.34**	0.39**	0.53**	0.74**	0.43**	1.00			
	E_2	-0.09	-0.55**	-0.11	0.13	0.34**	0.48**	0.68**	0.44**	1.00			
	E_3	0.08	-0.23**	0.13	0.29**	0.50**	0.46**	0.51**	0.57**	1.00			
	E_4	-0.03	-0.25**	0.01	0.51**	0.60**	0.57**	0.09	0.63**	1.00			
X_{10} 100 seed weight	E_1	0.23**	0.24**	0.27**	-0.10	-0.09	0.15*	0.05	-0.05	0.11	1.00		
	E_2	0.34**	0.26**	0.36**	0.08	-0.18*	0.03	-0.02	-0.11	-0.09	1.00		
	E_3	0.16*	0.13	0.17*	0.01	0.10	0.18*	0.06	0.07	0.09	1.00		
	E_4	0.31**	0.15*	0.30**	0.14*	0.08	0.05	0.07	0.09	0.11	1.00		
X_{11} Oil content	E_1	0.11	0.16*	0.10	0.02	-0.02	0.03	-0.01	-0.09	-0.06	0.17*	1.00	
	E_2	0.17*	0.24**	0.19**	-0.08	-0.03	-0.03	-0.09	-0.14*	-0.14*	0.01	1.00	
	E_3	-0.11	0.18*	-0.08	-0.11	-0.11	-0.16*	0.01	-0.12	-0.13	0.08	1.00	
	E_4	-0.06	0.00	-0.11	-0.11	-0.03	-0.01	-0.10	0.03	0.03	0.10	1.00	
X_{12} Seed yield/plant	E_1	0.13	0.00	0.13	0.26**	0.31**	0.53**	0.68**	0.37**	0.94**	0.42**	0.01	1.00
	E_2	0.00	-0.50**	-0.03	0.16**	0.27**	0.47**	0.68**	0.39**	0.87**	0.14*	-0.12	1.00
	E_3	0.14*	-0.13*	0.19**	0.29**	0.51**	0.52**	0.54**	0.57**	0.81**	0.47**	-0.06	1.00
	E_4	0.10	-0.15*	0.12	0.52*	0.58*	0.54*	0.12	0.60*	0.89**	0.48*	0.08	1.00

*, ** Significant at 5% and 1% level, respectively.

@ E_1 = summer, 1992 at Tindivanam; E_2 = Summer, 1992 at Cuddalore; E_3 = *Kharif*, 1993 at Tindivanam; E_4 = *Kharif*, 1993 at Cuddalore

Table 2 *Phenotypic path coefficients analysis* showing the direct and indirect effects of eleven characters on yield of castor in four different environments

		E@	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	'r' with seed yield
X_1	Days to 50% flowering	E_1	**0.00**	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.07	0.00	0.13
		E_2	**0.00**	-0.04	-0.01	0.00	0.00	0.00	0.02	0.00	-0.06	0.08	0.00	0.00
		E_3	**-0.03**	0.01	0.06	0.00	0.00	0.00	-0.01	0.00	0.05	0.06	0.00	0.14
		E_4	**0.09**	0.02	-0.07	0.00	0.00	-0.02	0.00	0.00	-0.03	0.11	0.00	0.10
X_2	Plant height	E_1	0.00	**0.00**	0.01	0.00	0.00	0.00	0.00	0.00	-0.09	0.07	0.00	0.00
		E_2	0.00	**-0.10**	0.00	0.00	0.00	0.00	-0.05	0.00	-0.41	0.06	0.00	-0.50
		E_3	-0.01	**0.03**	0.03	-0.01	-0.01	-0.02	-0.04	-0.02	-0.13	0.05	0.00	-0.13
		E_4	0.05	**0.04**	-0.04	-0.01	-0.01	-0.04	0.00	-0.01	-0.20	0.06	0.00	-0.15
X_3	No. of nodes up to primary spike	E_1	0.00	0.00	**0.02**	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.00	0.13
		E_2	0.00	-0.04	**-0.01**	0.00	0.00	0.00	0.01	0.00	-0.08	0.08	0.00	-0.03
		E_3	-0.03	0.01	**0.07**	0.00	0.01	0.00	0.00	0.00	0.08	0.06	0.00	0.19
		E_4	0.08	0.02	**-0.08**	0.00	0.00	-0.01	0.00	0.00	0.01	0.11	0.00	0.12
X_4	No. of first order branches per plant	E_1	0.00	0.00	-0.01	**-0.02**	0.00	0.00	0.00	0.01	0.31	-0.03	0.00	0.26
		E_2	0.00	0.01	0.00	**0.02**	0.00	0.00	0.01	0.00	0.10	0.02	0.00	0.16
		E_3	0.00	-0.01	0.00	**0.05**	0.03	0.01	0.00	0.03	0.17	0.00	0.00	0.29
		E_4	-0.01	-0.01	0.00	**0.04**	0.02	0.02	0.00	0.01	0.39	0.05	0.00	0.52
X_5	No. of second order branches per plant	E_1	0.00	0.00	0.00	0.00	**-0.01**	0.00	-0.01	0.01	0.35	-0.03	0.00	0.31
		E_2	0.00	0.03	0.00	0.00	**-0.01**	0.00	0.04	0.01	0.25	-0.04	0.00	0.27
		E_3	0.00	0.00	0.01	0.02	**0.07**	0.01	0.03	0.05	0.29	0.04	0.00	0.51
		E_4	0.00	-0.01	0.00	0.03	**0.03**	0.03	0.00	0.02	0.47	0.03	0.00	0.58
X_6	Effective length of primary spike	E_1	0.00	0.00	0.00	0.00	0.00	**0.02**	-0.01	0.00	0.48	0.05	0.00	0.53
		E_2	0.00	0.03	0.00	0.00	0.00	**0.01**	0.08	0.00	0.35	0.01	0.00	0.47
		E_3	0.00	-0.01	0.00	0.01	0.02	**0.05**	0.10	0.03	0.27	0.07	0.00	0.52
		E_4	-0.02	-0.02	0.02	0.01	0.01	**0.07**	0.00	0.01	0.44	0.02	0.00	0.54
X_7	No. of capsules per primary spike	E_1	0.00	0.00	0.00	0.00	0.00	0.01	**-0.02**	0.00	0.67	0.02	0.00	0.68
		E_2	0.00	0.04	0.00	0.00	0.00	0.01	**0.14**	0.00	0.50	0.00	0.00	0.68
		E_3	0.00	-0.01	0.00	0.00	0.01	0.03	**0.16**	0.02	0.30	0.02	0.00	0.54
		E_4	0.00	0.00	0.00	0.00	0.00	0.01	**0.01**	0.00	0.07	0.02	0.00	0.12
X_8	No. of spike per plant	E_1	0.00	0.00	-0.01	-0.01	-0.01	0.00	-0.01	**0.01**	0.40	-0.02	0.00	0.37
		E_2	0.00	0.04	0.00	0.00	-0.01	0.00	0.05	**0.01**	0.32	-0.03	0.00	0.39
		E_3	0.00	-0.01	0.00	0.02	0.05	0.02	0.05	**0.07**	0.33	0.03	0.00	0.57
		E_4	-0.01	-0.01	0.01	0.02	0.02	0.03	0.00	**0.02**	0.49	0.03	0.00	0.60
X_9	No. of capsules per plant	E_1	0.00	0.00	0.00	-0.01	0.00	0.01	-0.02	0.01	**0.91**	0.04	0.00	0.94
		E_2	0.00	0.05	0.00	0.00	0.00	0.00	0.10	0.00	**0.74**	-0.02	0.00	0.87
		E_3	0.00	-0.01	0.01	0.02	0.03	0.02	0.08	0.04	**0.59**	0.03	0.00	0.81
		E_4	0.00	-0.01	0.00	0.02	0.02	0.04	0.00	0.01	**0.77**	0.04	0.00	0.89
X_{10}	100-seed weight	E_1	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.10	**0.31**	0.00	0.42
		E_2	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	**0.23**	0.00	0.14
		E_3	-0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.05	**0.37**	0.00	0.47
		E_4	0.03	0.01	-0.02	0.01	0.00	0.00	0.00	0.00	0.09	**0.36**	0.00	0.48
X_{11}	Oil content	E_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	0.05	**0.01**	0.01
		E_2	0.00	-0.02	0.00	0.00	0.00	0.00	-0.01	0.00	-0.11	0.00	**0.02**	-0.12
		E_3	0.00	0.01	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	-0.07	0.03	**0.01**	-0.06
		E_4	-0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.04	**0.02**	0.08
Residue		E_1	0.15											
		E_2	0.42											
		E_3	0.39											
		E_4	0.23											

@ E_1- summer 1992 at Tindivanam; E_2 –summer 1992 at Cuddalore; E_3 – *Kharif* 1993 at Tindivanam; E_4 – *Kharif* 1993 at Cuddalore

The estimated residual effect for different environments ranged from 0.15 to 0.42, indicating the adequacy and appropriateness of the characters chosen for path analysis. Among the characters, number of capsules/plant and 100 seed weight recorded very high and positive direct effect on seed yield. Though the characters, number of first order branches/plant, number of second order branches/plant, effective length of

primary spike and number of spikes/plant showed positive association with seed yield in correlation analysis, these characters had showed very low direct effects on seed yield. Previous reports suggest that capsules/ plant (Patel and Jaimini, 1988); capsules/ spike and second order branches (Bhatt and Reddy, 1981) had high positive direct effects on seed yield. The characters namely number of first order branches/plant, number of second order branches/plant, effective length of primary spike, number of capsules/primary spike and number of spikes/plant had average to high indirect effect via number of capsules/plant on seed yield.

Hence, considering the correlation and path analysis, it may be concluded that number of capsules/plant and 100 seed weight alone may be considered as selection indices for the selection criterion for seed yield improvement in castor breeding programme. These characters also showed consistent relationship with seed yield in all the environments.

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Short communication

Heterosis for seed yield per plant and its components in castor, *Ricinus communis* L.*

J.B. Patel and H.C. Pathak

Main Castor-Mustard Research Station, Sardarkrushinagar-Dantiwada Agricultural. University, Sardarkrushinagar-385 506, Gujarat

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Castor (*Ricinus communis* L.) is an important non-edible oilseed crop of arid and semi-arid of India, which belongs to Euphorbiaceae family. The phenomenon of heterosis has proved to be the most important genetic tool in enhancing the yield of self as well as cross pollinated crop species in general and castor in particular. The exploitation of heterosis on commercial scale in castor is regarded as one of the major breakthrough in the improvement in its productivity in Gujarat state, where the crop is grown under well managed irrigated condition. With the availability of stable pistillate lines in castor, exploitation of heterosis on commercial scale has become commercially feasible and economical (Gopani *et al.*, 1968). In genetic improvement, selection of suitable parents is one of the important step for development of better hybrids. Though *per se* performance is taken as selection criteria, proper information on magnitude of heterosis, combining ability and gene action for seed yield and its component characters involved in the inheritance in different parents and their crosses would be more helpful in selecting appropriate parents and desirable cross combinations for commercial exploitation of hybrid vigour (Dangaria *et al.*, 1987). The present study was, therefore, undertaken, to determine the extent of heterosis in castor and to identify heterotic hybrids.

The experimental material comprised of five pistillate lines (Geeta, VP-1, SKP-5, SKP-72 and SKP-93) and 10 male parents (VI-9, 48-1, 116-1, SPS-43-3, DCS-9, SH-72, SKI-73, SKI-107, SKI-80, and SKI-168). The parents were crossed in a L x T mating design and resulting 50 hybrids along with 15 parents were grown in Randomized Block Design with three replications in four environments during *Kharif*,1997-98. Environments were created by two different dates of sowing (normal *kharif* i.e. 1st week of August and late *kharif* i.e., 1st week of September) at two different locations *viz.*, Potato Research Station, GAU, Deesa and Agricultural Research Station, GAU, Talod. Parents and hybrids were randomized separately in each replication. Each genotype was grown in a single row of 12 plants with inter and intra row spacing of 90 cm x 60 cm. Recommended package of practices for irrigated condition were adopted . Observations were recorded on five randomly selected plants for each treatment in each replication and in each environment for yield and yield contributing parameters (Table 1). Each character was analysed separately using analysis of variance technique suggested by Panse and Sukhatme (1976) and heterosis was calculated in F_1 hybrids over better parent and check, GCH-4.

Analysis of variance in individual as well as on pooled basis revealed highly significant differences among genotypes, parents and hybrids for all the traits except oil content for parents on pooled basis indicating the presence of great deal of genetic variability among the parents and hybrids under study. The existence of overall heterosis was evident for seed yield/plant and other yield contributing traits from the significance of parents vs. hybrids in individual environments as well as pooled over environments except plant height and number of effective branches per plant in E_1, E_2 and on pooled basis.

The material was appropriate for the study of manifestation of heterosis and genetic parameters involved in the inheritance of different traits. Highly significant mean sum of squares due to genotypes x environments, parents x environments and hybrids x environments for all the characters indicated that the performance of genotypes, parents and hybrids were inconsistent in varying environments. The significance of parents vs. hybrids x environments for all the traits (except length of main raceme) indicated that differences between the average performance of hybrids and parents were inconsistent in varying environments except for length of main raceme.

The degree of heterosis varied from cross to cross for all the characters studied (Table 1). Overall, the magnitude of heterotic effects were high for seed yield/plant, plant height, length of main raceme, number of capsules on main raceme, number of effective branches/plant and total number of branches/plant; moderate for number of nodes upto main raceme and 100-seed weight; and low for days to 50% flowering, days to 50% maturity and oil content. In

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the present study, out of 50 crosses studied, 22 and 16 crosses depicted significant desirable heterobeltiosis and standard heterosis for seed yield/plant, respectively. Such crosses are also likely to give better transgressive segregants and could be used for the isolation of superior pistillate and inbred lines for further yield improvement. Earlier, Hooks *et al.* (1971), Yadava *et al.* (1978), Kaul and Prasad (1983) and Dangaria *et al.* (1987) have also reported high value of heterosis for seed yield/plant in castor. High heterosis might be due to parents of genetically diverse origin (Yadava *et al.*, 1978).

The cross combination, 'SKP-72 x SKI-80' depicted the highest heterobeltiosis (74.4%) with high seed yield/plant (292.2 g), whereas the cross combination, 'Geeta x SKI-107' exhibited the significantly highest standard heterosis (31.7%) and maximum seed yield/plant (322.6g) (Table 2).

Table 1 Range of heterosis over better parent (BP) and standard hybrid (SH) along with best cross and number of crosses showing significant heterosis in desired direction for various characters pooled over environments in castor

Character	Range of heterosis over		No. of crosses showing significant desirable heterosis	
	BP	SH	BP	SH
Seed yield/plant (g)	-16.15 to 74.39 (SKP-72 x SKI-80)	-22.00 to 31.72 (Geeta x SKI-107)	22	16
Days to 50% flowering	-6.69 to 1.87 (SKP-5 x 116-1)	-2.83 to 9.93 (VP-1 x SKI-107)	31	2
Days to 50% maturity	-8.06 to 5.52 (SKP-5 x SPS-43-3)	-0.84 to 8.03 (SKP-93 x SKI-73)	26	1
Plant height (cm)	-29.42 to 161.77 (SKP-5 x 48-1)	-41.80 to 50.41 (VP-1 x SKI-107)	10	20
No. of nodes upto main raceme	-17.17 to 30.51 (SKP-93 x VI-9)	-18.79 to 25.74 (VP-1 x SKI-73)	25	17
Length of main raceme (cm)	-48.82 to 37.91 (VP-1 x 48-1)	-21.30 to 42.41 (SKP-72 x SKI-73)	18	26
No. of capsules on main raceme	-48.36 to 75.41 (VP-1 x DCS-9)	-27.19 to 53.98 (SKP-72 x SPS-43-3)	17	31
No. of effective branches/plant	-43.33 to 10.74 (VP-1 x SKI-73)	-8.81 to 35.23 (Geeta x SKI-107)	5	28
Total number of branches/plant	-36.32 to 2.47 (VP-1 x SKI-73)	-7.61 to 36.86 (Geeta x SPS-43-3)	-	22
100-seed weight (g)	-14.79 to 12.67 (SKP-5 x SKI-168)	-3.99 to 22.56 (SKP-72 x SKI-80)	16	38
Oil content (%)	-0.83 to 1.24 (Geeta x VI-9)	-0.39 to 1.49 (Geeta x VI-9)	22	36

NB: For traits DF, DM, PH and NN, negative heterosis is desirable.

Table 2 Promising hybrids for seed yield/plant with standard heterosis (H_3) and heterobeltiosis (H_2), along with their *sca* effect and component traits showing significant desirable standard heterosis pooled over environments in castor

Hybrid	Seed yield/plant (g)	Heterosis (%)		*sca* effects	Significant desirable standard heterosis for component traits
		H_3	H_2		
Geeta x SKI-107	322.6	31.7**	11.7**	27.5**	LR, EB, TB, TW, O
Geeta x VI-9	307.7	25.7**	6.5	33.3**	EB, TB, TW, O
SKP-5 x SKI-73	304.4	24.3**	10.1**	33.6**	CR, O
Geeta x 116-1	299.2	22.2**	3.6	24.7**	LR, CR, EB, TB
Geeta x SKI-73	294.3	20.1**	1.9	14.8**	NN, EB, TB, O
SKP-72 x SKI-80	292.2	19.3**	74.4**	31.6**	PH, NN, LR, CR, EB, TW
SKP-5 x SH-72	282.0	15.2**	2.0	9.3	LR, CR, EB, TB, TW
SKP-5 x SKI-107	280.0	14.3**	1.3	-6.5	LR, CR, EB, TW, O
SKP-5 x 48-1	279.1	13.9**	1.0	6.9	CR, EB, TB, TW, O
SKP-5 x DCS-9	276.4	12.8**	-0.0	20.0**	NN, LR, CR, EB, TB, TW, O
VP-1 x SKI-168	273.4	11.6**	15.9**	32.1**	PH, EB, TB, O
VP-1 x SKI-107	272.9	11.4**	19.4**	6.0	DF, PH, NN, LR, CR, EB, TB, TW
VP-1 x SKI-80	272.2	11.1*	62.4**	17.8**	PH, NN, LR, CR, EB, TB, O
SKP-72 x SH-72	271.5	10.9*	38.7**	12.0*	LR, CR, TW
Geeta x SKI-168	270.8	10.6*	-6.3	1.4	EB, TB, TW, OS
GCH-4	244.9				
SEm±	13.1		10.7	5.9	

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

DF = Days to 50% flowering, DM = Days to 50% maturity, NN = No. of nodes upto main raceme, LR = Length of main raceme, CR = No. of capsules on main raceme, EB = No. of effective branches/plant, TB = Total no. of branches/plant, TW = 100-seed weight and O = oil content

The identification and utilization of heterotic and useful crosses are very important in hybrid breeding approach in order to make commercial cultivation of hybrid beneficial. A comparison of 15 promising hybrids which were found significantly superior to GCH-4 in respect of seed yield/plant, revealed that on pooled basis, Geeta x SKI-107 (31.7%), Geeta x VI-9 (25.7%) and SKP-5 x SKI-73 (24.3%) were the most heterotic hybrids showing the significant highest standard heterosis, whereas SKP-72 x SKI-80 (74.4%), VP-1 x SKI-80 (62.4%) and SKP-72 x SH-72 (38.7%) exhibiting significantly highest heterobeltiosis were the best hybrids for seed yield/plant. Out of the 15 promising hybrids, 10 hybrids registered significant positive sca effects for seed yield/plant, indicating the involvement of non-additive gene action in the heterotic response of the hybrids. The results also revealed that high heterosis observed for seed yield/plant might be due to the heterosis observed for their important yield contributing traits like length of main raceme, number of effective branches/plant, total number of branches/plant, 100-seed weight and oil content for Geeta x SKI-107, number of effective branches/plant, total number of branches/plant, 100-seed weight and oil content for Geeta x VI-9 and number of capsules on main raceme and oil content for SKP-5 x SKI-73. High association of heterosis between seed yield/plant and other yield contributing traits in castor have also been reported by Thakkar (1987) and Mehta (1989).

Therefore, the hybrids Geeta x SKI-107, Geeta x VI-9 and SKP-5 x SKI-73 showing significant highest standard heterosis can be utilized further for commercial exploitation of hybrid vigour and also for the development of superior parental lines through selection in segregating generations in view of significant sca effects.

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Short communication

Genetic divergence analysis in safflower, *Carthamus tinctorius* L.[1]

K.M. Pawar, B.M. Joshi, P.K. Jagtap and S.S. Jawanjal

Department of Genetics and Plant Breeding, Marathwada Agricultural University, Parbhani-431 402, Maharashtra

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Safflower (*Carthamus tinctorius* L.) Is an important *rabi* oilseed crop grown on residual soil moisture, referred to as drought tolerant crop. Safflower is grown in about 1.2 m.ha with annual production of 0.79 m.tonnes (Anonymous, 2003). Genetic variability of divergence present in the material plays a vital role in framing successful breeding programmes. The D^2 statistic analysis Mahalanobis (1936) has been extensively used for such studies in other crops. Therefore, efforts have been made to determine the wide genetic divergence among different genotypes useful for future hybridization programme in safflower.

A field experiment involving 121 safflower germplasm accessions and six released varieties *viz.*, Sharada, Bhima, Annigeri-1, HUS-305, Manjira and JSF-1 was laid out in a Randomized Block Design with two replications during *rabi*, 2000-01 at experimental farm of Agricultural Botany, Marathwada Agricultural University, Parbhani. Each germplasm accession was sown in a single row of 5 m length with a spacing of 45 x 20 cm. Observations were made on five randomly selected competitive plants per treatments in each replications on 10 different characters. The genetic divergence was accessed using Mahalanobis's D^2 statistic. The accessions were grouped according to the method described by Tocher (Rao, 1952).

Results of D^2 analysis revealed that the genotypes differ significantly for all the 10 characters. The analysis for estimating the contribution of different characters towards genetic diversity indicated that oil content, plant height, days to 50 % flowering and number of branches/plant contributed maximum to the total genetic divergence. This supports the result of Ranga Rao *et al.* (1980) and Patil *et al.* (1984).

Genotypes were grouped into 15 clusters following Tocher's method described by Rao (1952). The distribution of different genotypes revealed that the cluster I having the maximum number of genotypes followed by Cluster III with 10 genotypes, cluster II, V and XIII had 6, 3 and 2 genotypes while remaining have clusters having single genotypes i.e., monogenotypic. The similar observations were also reported by Patel *et al.* (1989).

A considerable intercluster variation was seen among the cluster means for most of the characters. The cluster means for seed yield (g), oil content (%), number of seeds/capitulum and 100 seed weight were highest in the cluster IX, XIII, VI and XII, respectively while the cluster means for number of capitula/plant, number of primary and secondary branches/plant were highest in case of cluster VII. The earliest genotypes for maturity was found in cluster XI while dwarf plant in the cluster IV.

The intracluster distance varies from 0.00 to 21.34, the maximum being observed for cluster V which consists of 3 germplasm lines with more variability (Table 1). The maximum intercluster distance was observed between the cluster XV and XIII followed by cluster XV and X, cluster XV and II and cluster XV and XI, respectively. While, closest proximity was noticed between cluster IX and VI. The results are in accordance with Patil *et al.* (1984).

The mutual relationship among various clusters based on generalized distance has been diagrammatically shown in Fig. 1. Clusters separated by the largest statistical distance showed the maximum divergence, such as clusters XII and XV, X and XV, IX and XV and between VI and XV whereas, clusters close to each other exhibit less diversity. Crosses among divergent parents are likely to yield desirable combinations. Therefore, crossing programme should be initiated between genotypes belonging to different clusters. Two important points to be considered: (I) choice of the particular cluster from which genotypes are to be used as parent in a crossing scheme and (ii) selection of particular genotypes from the selected groups.

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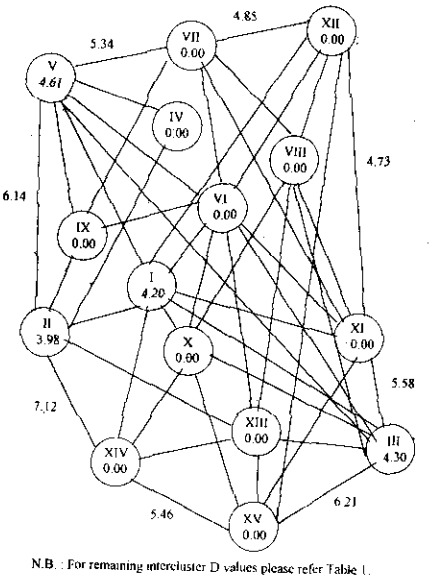
Table 1 Average intercluster and intracluster (Bold) distances in Tocher's scheme

Clusters	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 I	**17.64**	24.83	24.83	22.93	23.43	21.68	23.53	23.38	21.76	23.17	21.81	23.85	29.05	35.41	51.72
	(4.2)	(4.98)	(4.98)	(4.78)	(4.84)	(4.65)	(4.85)	(4.83)	(4.66)	(4.81)	(4.67)	(4.88)	(5.38)	(5.95)	(7.19)
Cluster II		**15.92**	33.22	37.15	37.72	28.23	25.19	30.92	26.24	24.00	31.44	32.39	25.78	50.73	62.88
		(3.98)	(5.76)	(6.09)	(6.14)	(5.31)	(5.01)	(5.56)	(5.12)	(4.89)	(5.60)	(5.69)	(5.07)	(7.12)	(7.92)
Cluster III			**18.55**	27.66	23.88	28.46	32.57	22.24	32.31	31.95	31.14	26.75	40.75	27.36	38.63
			(4.30)	(5.25)	(4.88)	(5.33)	(5.70)	(4.71)	(5.68)	(5.65)	(5.58)	(5.17)	(6.38)	(5.23)	(6.21)
Cluster IV				**0.00**	21.20	24.22	36.10	33.30	30.04	27.76	20.68	31.99	36.91	28.97	51.56
				(0.00)	(4.60)	(4.92)	(6.00)	(5.77)	(5.48)	(5.26)	(4.54)	(5.65)	(6.07)	(5.38)	(7.18)
Cluster V					**21.34**	26.52	28.53	21.51	27.64	34.76	27.71	25.51	42.12	23.65	40.49
					(4.61)	(5.14)	(5.34)	(4.63)	(5.25)	(5.89)	(5.26)	(5.05)	(6.48)	(4.86)	(6.36)
Cluster VI						**0.00**	23.12	24.94	14.39	24.75	26.69	26.35	33.37	41.48	56.22
						(0.00)	(4.80)	(4.99)	(3.79)	(4.97)	(5.16)	(5.13)	(5.77)	(6.44)	(7.49)
Cluster VII							**0.00**	17.65	15.17	31.57	32.04	23.57	34.54	44.41	55.54
							(0.00)	(4.20)	(3.89)	(5.61)	(5.66)	(4.85)	(5.87)	(6.66)	(7.45)
Cluster VIII								**0.00**	21.70	34.50	32.82	18.07	36.69	32.26	39.36
								(0.00)	(4.65)	(5.87)	(5.72)	(4.25)	(6.30)	(5.67)	(6.27)
Cluster IX									**0.00**	28.67	28.78	24.15	30.53	44.88	57.12
									(0.00)	(5.35)	(5.36)	(4.91)	(5.52)	(6.69)	(7.55)
Cluster X										**0.00**	15.79	25.83	17.08	43.93	64.47
										(0.00)	(3.97)	(5.08)	(4.13)	(6.62)	(8.02)
Cluster XI											**0.00**	22.38	22.52	36.25	60.09
											(0.00)	(4.73)	(4.74)	(6.02)	(7.75)
Cluster XII												**0.00**	30.07	33.56	46.29
												(0.00)	(5.48)	(5.79)	(6.80)
Cluster XIII													**0.00**	52.84	71.09
													(0.00)	(7.26)	(8.43)
Cluster XIV														**0.00**	29.89
														(0.00)	(5.46)
Cluster XV															**0.00**
															(0.00)

Fig. 1. Mutual relationship among clusters



N.B. : For remaining intercluster D values please refer Table 1.

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Short communication

Stability behaviour of TM cultures of Indian mustard [*Brassica juncea* (L.) Czern & Coss.] in arid region of Rajasthan

P.C. Gupta, Shiv Narayan and R.K. Rathore

Agricultural Research Station, Rajasthan Agricultural University, Bikaner-334 006, Rajasthan

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High yielding varieties having inherent stability over diverse environments are of great significance in arid and semi arid regions of Rajasthan for sustainable production and productivity. Genotype x environment interaction is one of the genetic parameters responsible for the phenotypic stability and adaptability. In the present study an attempt has been made to identify stable genotypes for seed yield and it's components in Indian mustard.

The material for the present study consisted of seven TM cultures developed at BARC, Trombay *viz.*, TM 7, TM 17, TM 28, TM 31, TM 35, TM 36 and TM 49 and three commercial varieties of Indian mustard *viz.*, Varuna, Bio 902 and Kranti. A set of these 10 genotypes was evaluated in randomized complete block design with three replications during *rabi*, 2001-02, 2002-03 and 2003-04 at Agricultural Research Station, Bikaner. In each year sowing was done during the first weak of November. Each genotype was raised in five rows of 5 m length with inter and intra row spacing of 30 and 10 cm, respectively. The recommended fertilizer of 30kg N+ 40kg P_2O_5+ 40kg S/ha was broadcasted at the time of sowing, while 30kg N was top-dressed at the time of 1st irrigation. A total of five irrigations were applied during the crop season. Observations on days to 50 % flowering, days to maturity, test weight (g) and seed yield (q/ha) were recorded on plot basis, while secondary branches per plant, length of main raceme (cm) and siliquae/plant were recorded on five randomly selected competitive plants. Stability analysis for these traits was done using stability model proposed by Eberhart and Russell (1966).

Analysis of variance showed that genotype x environment interaction was significant for all the seven characters (Table 1) indicating that the genotypes interacted strongly with the environments. Variance due to genotypes and environments for most of the characters were significant indicating substantial variability among the genotypes and environments. Among the components of G x E interaction, the variance due to pooled deviation alone registered significance for all the seven characters. It indicated that the performance of genotypes was unpredictable over environments for these characters due to preponderance of non-linear component. However, G x E (linear) mean squares were found significant for days to maturity and test weight indicating the presence of both predictable and non-predictable components for these traits.

All the genotypes were significant for linear component (b_i) for seed yield. However, two genotypes were also significant for nonlinear component (S^2d_i) of genotype x environment interaction; indicating thereby, genotype x environment interaction was linear in nature, suggesting possibility of prediction for seed yield across the environments. This was also confirmed from overall information obtained from pooled analysis of variance, where linear genotype x environment was almost 1.78 times more than the nonlinear genotype x environment variance.

Stable performance of individual genotype was judged on the basis of its regression coefficient (b_i) and deviation from regression (S^2d_i) along with it's per se performance (Table 2). Among the components of seed yield, ten and five genotypes for days to 50% flowering, nine and four for days to maturity, six and two for secondary branches/ plant, seven and two for length of main raceme, four and three for siliquae/plant and three and five genotypes for test weight were significant for linear and nonlinear component of genotype x environment respectively, indicating the preponderance of linear component of genotype x environment interaction in the inheritance of these traits and suggesting the prediction can be possible across the environments.

While considering the individual parameter of stability for yield components, it revealed that genotype TM 28 for days to 50% flowering, TM 7 and TM 31 for days to maturity, TM28 and TM31 for secondary branches/plant, TM 49 for length of main raceme, TM 17 and TM 31 for siliquae/plant and TM 28 and Bio 902 for test weight were found stable because of high mean with average responsiveness and least deviation from regression. The genotype TM 17 and TM 35 for days to maturity and Kranti for secondary branches/plant and length of main raceme possessed high mean with high responsiveness and low deviation from regression indicating suitable for favourable environments (below average stability). While genotype Varuna for length of main raceme and TM 28 for siliquae/plant had high mean with low responsiveness indicated their suitability for these traits for poor environments (above average stability).

Table1 ANOVA for stability analysis

Source	d.f.	Mean sum of squares						
		Days to 50% flowering	Days to maturity	Sec. branches /plant	Length of main raceme	Siliquae/ plant	Test weight	Seed yield
Genotypes	9	10.97**	7.60	29.62*	132.07*	10182.79	2.96**	5.94
Environments	2	210.68**	125.42**	97.21**	2518.67**	30285.55*	2.79**	254.75**
Genotypes x Environments	18	1.28**	5.79**	10.21**	44.44*	5412.71**	0.25**	4.89**
Environments + (Genotypes x Environments)	20	22.22**	17.75**	18.91*	291.86**	7899.99	0.52	2.98
Environment (Linear)	1	421.36**	250.80**	194.43**	5037.32**	60571.52*	5.58**	509.50**
Genotypes x Environments (Linear)	9	1.08	10.42**	14.43	29.10	3372.20	8.46**	6.03
Pooled Deviations	10	1.33**	1.04**	5.38**	53.80*	6707.82**	0.42**	3.38**
Pooled Error	54	0.34	0.33	2.15	20.74	739.08	0.03	1.07

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

Table 2 Stability parameters for different characters in Indian mustard

Genotype	Days to 50% flowering			Days to maturity			Secondary branches/plant			Length of main raceme		
	x_i	b_i	S^2d_i	x_i	b_i	S^2d_i	x_i	b_i	S^2d_i	x_i	b_i	S^2d_i
TM 7	52.0	0.91 **	2.66 **	117.2	1.01**	0.94	14.3	0.41***	-1.42	66.6	0.60**#	-14.91
TM 17	50.3	0.83 *	3.33 **	116.4	0.46**#	-0.29	13.8	-0.28	15.56**	69.4	1.04*	46.65
TM 28	49.0	1.00 **	-0.34	118.6	2.72**	-0.32	17.4	1.15**	0.11	71.7	1.18**	8.14
TM 31	51.7	0.86 **	1.56 *	117.1	0.87**	0.48	20.4	2.41**	5.32	74.2	1.05	222.86**
TM 35	49.4	0.81 **	1.10 *	115.2	0.52**#	0.13	14.3	0.71**#	-2.13	67.2	0.96**	-18.33
TM 36	49.1	1.10 **	2.13 **	114.9	0.51	1.11*	15.7	0.79	0.91	59.6	0.85**	6.78
TM 49	54.1	0.91 **	0.23	119.2	1.01*	2.23**	16.2	0.66	4.12	75.8	1.24	3.33
Varuna	52.3	1.12 **	-0.30	117.9	0.92**	-0.07	23.6	1.87	13.22**	71.8	0.63	31.37
Kranti	53.6	1.23**	-0.30	119.2	0.92*	1.79*	17.7	0.23**#	-2.12	82.1	1.23**	-18.32
Bio-902	53.3	1.24**	-0.12	119.0	1.06**	1.17*	14.7	2.04**	-1.87	79.9	1.22*	62.90*
Mean	51.5			117.5			16.8			71.8		

Table 2 (Contd...)

Genotype	Siliquae/plant			Test weight			Seed yield (q/ha)		
	x_i	b_i	S^2d_i	x_i	b_i	S^2d_i	x_i	b_i	S^2d_i
TM 7	294.3	0.62**#	-735.24	4.9	0.55	0.02	13.60	0.89**#	-1.07
TM 17	330.4	0.91*	-93.70	4.5	0.54	0.01	13.54	0.25**#	-1.06
TM 28	338.2	1.28	2230.13	6.5	0.90**	-0.04	15.04	0.90 *	5.65*
TM 31	391.3	2.17**	816.46	4.8	0.53	0.40**	15.13	0.88 *	2.52
TM 35	271.1	0.77	582.63	6.6	1.56	0.96**	13.09	0.85*	3.05
TM 36	275.4	0.66	611.19	5.9	1.03	0.69**	15.67	1.30**	-0.56
TM 49	400.1	1.63	11415.93*	4.7	1.05	0.57**	13.64	1.12**	1.67
Varuna	266.3	1.57*	1724.46	7.2	1.57	1.27**	16.36	1.15**	-0.27
Kranti	397.8	-0.59	30059.49*	4.6	1.04**	-0.04	17.12	1.11**	-0.20
Bio-902	251.7	0.98	13065.94*	6.2	1.22**	-0.03	16.20	1.56 *	13.25**
Mean	321.7			5.6			14.93		

*,** Significant at 5% and 1% levels, respectively when tested against zero
***, # Significant at 5% and 1% levels, respectively when tested against unity

All the genotypes except TM 28 and Bio 902 showed linearity for seed yield and had non-significant deviation from regression. The genotypes TM31, Varuna, and Kranti had high seed yield with average responsiveness (b_i=1) and non-significant deviation from regression (S^2d_i) and hence, were considered average stable for seed yield across the environments. Among these stable genotypes for seed yield, the genotypes TM 31 was accompanied with average stability for days to maturity, secondary branches per plant and siliquae/plant. Genotype TM 36 had high seed yield with high responsiveness (b_i >1) and non significant deviation from regression depicted below average stability suggesting that this genotypes was more sensitive to changing environments and therefore, showed suitability for high yielding environments. Labana *et al.* (1980) and Thakur *et al.* (1992; 1997) also identified stable genotypes suitable for specific locations.

Thus, it was evident that stability parameters varied from genotype to genotype for various characters. Not a single genotype showed average stability for all the characters studied. It may be concluded that TM 31, Varuna and Kranti had consistence performance for seed yield across the environments. Hence, these genotypes would be quite useful for sustainable production in arid regions of Rajasthan.

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Short communication

Response of groundnut, *Arachis hypogaea* L. to dates of sowing, application of gypsum and micronutrients in western Rajasthan

M.S. Rathore, M.S. Chandawat and I. Singh

Agricultural Research Station, Rajasthan Agricultural University, Mandor-342 304, **Rajasthan**

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In western Rajasthan, availability of irrigation in recent years has improved the economic status of the farmers. During *kharif* season, there is very little choice of crops, which is high yielding and economical under harsh climatic conditions prevailing in the zone. Groundnut is an important oilseed crop well adapted to the diverse agro-climatic conditions. It has a high production potentiality and is very remunerative. It also provides good quality fodder. These characteristics of groundnut have created interest for its cultivation in this part of Rajasthan. Some farmers have also started its cultivation, but, no research work is being carried out to work out improved package of practices of groundnut cultivation in western Rajasthan. Hence, this experiment was conducted.

The studies were conducted during *kharif* 1998 and 2002 at Agricultural Research Station, Mandor. The soils were loamy sand in texture, poor in organic carbon (0.28%), medium in phosphorus (24 kg P_2O_5/ha), high in potash (325 kg K_2O/ha) and alkaline in nature (pH 8.1The treatment comprised of two dates of sowing (15th June and 1st July), two levels of gypsum (no gypsum and 250 kg/ha) and three levels of micronutrients (iron through ferrous sulphate @ 10 kg/ha, zinc through zinc sulphate @ 25 kg/ha and control). These 12 treatment combinations were laid out in Split Plot Design keeping dates of sowing and gypsum in the main plots and micronutrients in sub-plots. The treatments were replicated four times. Due to acute drought and unavailability of water for irrigation, the experiment could not be taken during the *kharif* seasons of 1999, 2000 and 2001. The crop was supplied with N : P_2O_5 @ 15 : 40 kg/ha through DAP. Groundnut cultivar, M-13 was sown at 45 x 10 cm spacing. The seeds were treated first with bavistin @ 3 g/kg seed, then the chloropyriphos and last with rhizobium culture. Irrigations were applied as er need of the crop. About 210 and 285 mm rainfall was received during *kharif* 1998 and 2002, respectively.

It was observed that sowing time significantly influenced the yield attributes and yield of groundnut (Table 1). The crop sown on 15th June produced plant with significantly better yield attributes (*viz.*, pod yield/plant, shelling per cent and seed index), pod and fodder yield in comparison to the crop sown on 1st July. This significant improvement in yield attributes and yield of groundnut crop sown on 15th June could be ascribed to effectiveness of the crop to exploit favourable environmental condition toward pod formation. Due to indeterminate growth habit of groundnut, it is assumed that at later stage both the vegetative and reproductive structures compete each other for nutrients and metabolites, whereas higher availability of metabolites/nutrients to sink in early sown crop have resulted in higher crop yields. Kumar *et al.* (2003) also reported similar results. Crop sown on 15th June produced 3980 and 11900 kg/ha, pod and fodder yield which was found to be 673 and 12500 kg/ha respectively more over 1st July sown crop (Table 1). Maximum net returns of Rs. 72330/ha was also obtained by sowing the groundnut on 15th June.

Gypsum application caused significant improvement in yield attributes, oil content inn seed, pod and fodder yield of groundnut over no gypsum during both the seasons. This significant improvement due to gypsum application could be ascribed due to the fact that gypsum is a source of sulphur and calcium. The role of sulphur in increasing the yield of groundnut is well documented, as it is required in the synthesis of sulphur containing amino acids, proteins, chlorophyll and oil. It also promotes nodulation. Presence of calcium in adequate quantities in fruiting zone is necessary for proper filling of pods, because the xylem vessels in the gynophores of groundnut are too narrow to permit the movement of calcium ions in quantities needed to meet growing demand of rapid developing kernels and pods shell. These results are in close proximity with the finding of Singh *et al.* (1993), Chobey *et al.* (2000) and Rao and Shaktawat (2002). Two seasons mean data showed that with application of gypsum an increase to the extent of 10.7 and 7.3% in pod and fodder yield of groundnut was noted over no gypsum application. Gypsum application also enhanced mean net income by 14.9% over no gypsum.

Table 1 Response of groundnut to date of sowing, application of gypsum and micro-nutrient on yield attributes, yield and net returns (two seasons pooled)

Treatment	Pod yield (kg/ha)	Pod yield/ plant (g)	Seed index (%)	Shelling (%)	Oil content (%)	Fodder yield (kg/ha)	Net returns (Rs/ha)
Sowing date							
15th June	3980	28.3	61.7	56.6	47.94	11900	72330
1st July	3307	19.7	59.6	53.6	47.44	10700	59780
CD (P=0.05)	495	3.8	1.4	2.0	NS	671	2940
Gypsum							
With gypsum	3881	27.2	62.2	56.4	48.98	11700	70630
Without gypsum	3507	20.9	59.1	53.8	46.40	10900	61480
CD (P=0.05)	495	3.8	1.4	2.0	0.74	671	2940
Micronutrients							
FeSO4	3801	27.5	62.5	56.2	47.76	11200	66890
ZnSO4	3719	24.3	61.3	55.5	47.63	11400	64920
Control	3559	20.3	58.1	53.5	47.69	11200	66360
CD (P=0.05)	421	2.3	1.9	1.9	NS	NS	NS

The role of micronutrients on increasing pod yield of groundnut was inconsistent. Amongst micronutrients, application of ferrous sulphate recorded significant improvement in yield parameters of groundnut during both the seasons in comparison to control. Significant impact on pod yield due to micronutrients application over control was recorded in the year 2002 only. Since, the soil of experiment site was alkaline calcareous in nature application of FeSO4 might have enhanced the availability of iron to the plant which was required for chlorophyll synthesis. Higher chlorphyll had improved photosynthesis and ultimately the yield. Sahu and Singh (1987) also reported similar effect of iron on pod yield of groundnut. Data further show that no significant improvement in net income was obtained with application of micronutrients.

On the basis of two seasons experimental results it can be concluded that to obtain higher pod yield and economic returns in western Rajasthan the groundnut should be sown on 15th June and gypsum (250 kg/ha) should be applied.

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Short communication

Effect of sulphur on seed yield, oil content and oil yield of sunflower, Helianthus annuus L.

Madhurendra, N. Prasad and J.N. Sah[1]

Department of Biochemistry, Rajendra Agricultural University, Pusa-848 125, Bihar

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In recent years, sunflower gained importance due to its wider adaptability and rich source of polyunsaturated fatty acid. However, decreased productivity is attributed to inadequate, seed filling related to source sink concept (Sirohi and Abrol, 1991). Sulphur fertilization is most critical for seed yield, oil and protein synthesis and for improvement of quality of produce by their enzymatic and metabolic efforts (Kumar et al., 1981). The soils are deficient in sulphur in Tirhut Zone of Bihar. Therefore, a study was made to find out the optimum dose and source of sulphur for sunflower crop for optimum seed yield, oil content and oil yield. The information on optimum dose of sulphur in not available under Tirhut region of Bihar.

A field experiment was conducted at Agriculture College farm, Dholi during *rabi* season of 2004. Nine treatments comprise of 4 sources of sulphur *viz.*, ammonium sulphate, single super phosphate (SSP), gypsum and elemental sulphur and 2 level of S (20 and 40 kg/ha) and an absolute control were tested in a Randomized Block Design with 3 replications. Sowing was done on November, 2004 with a spacing of cross, 4.2 m x 4.5 m (7 rows) and commons irrigation was given twice at the interval of 30 days and 55 days of crop period. The crop was harvested on March, 2005 from the net plot (3.0 m x 3.9 m, 5 row) air dried and threshed. The yield and oil content were recorded. Oil content was estimated by NMR technique (new port MK IIIA) analyzer. Oil yield was computed.

The data presented in table 1 showed that different level of sulphur had significant influence on seed yield. Maximum seed yield of 1256 kg/ha was obtained through ammonium sulphate (40 kg/ha i.e., T6 which was significantly superior to lower doses. The difference between sources as well as level of S were significant. Similar results were reported by Reddy et al. (1997) and Sreemannarayana *et al.* (1994).

Table 1 Seed yield, oil content and oil yield in sunflower as influenced by sulphur levels

	Treatment	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
T_1	Control (No sulphur only NPK as DAP and MOP or Urea)	771	27.2	209
T_2	Ammonium sulphate 20 kg/ha	1082	30.4	328
T_3	Single super phosphate 20 kg/ha	1095	30.8	337
T_4	Gypsum 20 kg/ha	970	31.6	306
T_5	Elemental sulphur 20 kg/ha	821	30.2	248
T_6	Ammonium sulphate 40 kg/ha	1256	30.0	378
T_7	Single super phosphate 40 kg/ha	1207	30.5	367
T_8	Gypsum 40 kg/ha	1020	30.5	311
T_9	Elemental sulphur 40 kg/ha	920	30.4	280
	SEm±	0.08	0.67	6.2
	CD (P=0.05)	0.23	1.72	18.7

[1] AICRP (Sunflower), TCA, Dholi, Muzaffarpur, Bihar.

Oil content in sunflower seeds did not vary due to different S-sources (ES, GY, AS, SSP). Every increment dose of S *(0, 20, 40 kg/ha) corresponding increase oil content upto* 40 kg/ha but difference were not significant beyond 20 kg S/ha. Similar result have been also reported by Singh and Sahu (1986). Oil yield is directly related to seed yield and oil content in seeds. Control plot produced markedly the lowest oil yield correlation between oil (%) and oil yield was significant and positive ($r=0.599$, $P < 0.01$). The study indicated that application of 40 kg S/ha through ammonium sulphate, single super phosphate, in order of preference is helpful in achieving high productivity with respect to oil content and oil yield. In fatty acid synthesis, acetyl co-enzyme A is converted to malonyl co-enzyme. The activity of this enzyme depends upon sulphur supply. Moreover, acetyl co-enzyme A itself contains sulphur and sulphohydryl group (Karle *et al.*, 1985). This might be the reason for increasing the oil content of sunflower with sulphur application.

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Short communication

Growth, seed yield and seed quality of sunflower, *Helianthus annuus* Linn. cultivars in Mollisols of Uttaranchal

M.S. Pal and S.P. Singh

Department of Agronomy, College of Agriculture, G.B. Pant Univ. of Agril. & Technology, Pantnagar-263 145, Uttaranchal

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The importance of oilseed in Indian economy is a paramount and oilseeds are second major group next to cereals. Sunflower (*Helianthus annuus* Linn.) is an important oilseed crop after soybean and palm in the world edible oil production. In the *Tarai* region of Uttaranchal and Uttar Pradesh, the continuous mono of rice-wheat system has not only stagnated the yield potential of the system but also deteriorated the soil environment because of nutrients exhaustion and incidence of insect pests and diseases. Further, the late sowing of wheat after late rice persistence is not profitable as that of spring sunflower. Similarly, the spring sunflower may be grown in the vacant fields after potato, sugarcane ratoons, green pea and rapeseed-mustard to increase the cropping intensity and also oilseed production. The number of sunflower hybrids are available for commercial cultivation and have not been tested during the spring season. Therefore, the field experiment was carried out to evaluate the production potential and seed quality of sunflower hybrids in the *Tarai* regior. of Uttaranchal during spring season.

Field experiment was carried out during spring, 1999 at Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttaranchal. The experimental site was silty loam with soil pH, organic carbon, total nitrogen, available phosphorus and potassium of 6.75, 1.06%, 0.079%, 56 kg/ha and 374 kg/ha, respectively. Ten sunflower cultivars *viz.*, Morden (open pollinated), Sungene-85, Jwalamukhi, PSFH-67, MSFH-8, MSFH-51, NSFH-999, GK-2004, No. 6460 and No. 3301 (Hybrids) were sown on 28th February under Randomized Block Design and replicated thrice. All cultivars were sown at 60 cm x 30 cm spacing with 8 kg/ha seed rate and 120, 60 and 40 kg N, P_2O_5 and K_2O/ha, respectively. The half N and full P and K were applied as basal and remaining half N was applied in two equal doses at 25 and 45 days after sowing (DAS), respectively. The crop was protected from insects-pest by spraying of endosulfan @ 1.5 ml/l water at 45 and 60 DAS. The drymatter accumulation, leaf area and yield attributes were observed at 25, 50 and 75 DAS and at harvest. The seed oil was extracted with the help of soxhlet method and protein content by multiplying of N content in seed with 6.25.

Sungene-85 had the highest drymatter at both 25 and 50 DAS because of its faster growth at early crop growth stages than other cultivars but, MSFH-8 gave the highest drymatter at 75 DAS and at harvest, that was statistically at par with NSFH-999 at 75 DAS and NSFH-999, No. 3301, MSFH-51 and No. 6460 at harvest. Morden gave the lowest drymatter at harvest because of lower plant height than all other hybrids.

The yield attributes, seed yield, harvest index, oil and protein contents different significantly with cultivars (Table 1). The highest head diameter was noticed in No. 3301 that remained non-significant with MSFH-8 and NSFH-999. The highest head weight was recorded in MSFH-8 that was statistically at par with NSFH-999. All hybrids had higher head weight than Morden because of larger head size and better seed setting. The 1000 seed weight was found greater in MSFH-8 followed by NSFH-999, MSFH-51, No. 3301 and No. 6460. Higher seed weight/plant was recorded in MSFH-8 that did not differed significantly with NSFH-999 and No. 3301. All hybrids had higher seed weight/plant than Morden because of higher head weight. Hybrid MSFH-8 gave significantly highest seed yield because of its higher yield attributes. Morden gave the lowest seed yield. Hybrid MSFH-8 gave 70% higher seed yield than Morden. Other hybrids *viz.*, NSFH-999, MSFH-51 and No. 3301 also performed better and yielded 4.2, 11.0 and 13.3% lower seed yield than MSFH-8. Reddy *et al.* (2005) reported that the hybrids like MSFH-8, PAC-36 and KBSH-1 were superior to Modern variety.

The harvest index (HI) varied significantly among cultivars and Morden recorded higher HI 40.6% because it produced comparatively higher seed weight/plant. Among hybrids, Sungene-85 had higher HI 38.6 followed by PSFH-67, Jwalamukhi, No. 3301 and MSFH-51. Hybrid MSFH-8 gave higher seed oil content (433%) mainly due to its bolder seeds. The highest (43.3%) oil content was recorded in hybrid MSFH-8 that was statistically at par with NSFH-999 (43.2%), No. 3301 (42.3%), Sungene-85 (42.2%) and Jwalamukhi (41.5%). Significantly lowest value of oil content was recorded in Morden (36%) followed by GK 2004 (39.5%), MSFH-51 (40.5%) and No. 6460 (40.7) and PSFH-67 (41%). The higher oil content might be due to

bolder seeds and higher 1000 seed weight. Hybrid MSFH-8 gave the highest protein content 19-16% that was significantly equal to NSFH-999. The higher protein content was the result of higher nitrogen content in seeds. Thosar *et al.* (1991) and Reddy *et al.* (2005) found significant difference in oil content among cultivars. Reddy *et al.* (2005) also recorded higher oil content in hybrids than Modern variety. Dhawan *et al.* (1983) noticed significant difference in seed protein content among sunflower cultivars.

Table 1 Effect of cultivars on yield attributes, seed yield, harvest index, oil and protein content of sunflower

Cultivar	Head diameter (cm)	Head weight/ plant (g)	Seed weight/ plant (g)	1000 seed weight (g)	Seed yield (kg/ha)	Harvest index (%)	Oil content (%)	Protein content (%)
Morden	17.6	103.3	46.3	47.2	1753	40.67	36.0	15.5
Sungene-85	17.9	107.1	47.0	49.0	1853	38.56	42.2	16.0
Jwalamukhi	17.4	119.1	52.1	52.8	2158	32.86	41.5	17.0
PSFH-67	18.2	114.0	50.4	49.7	2063	33.83	41.3	16.8
MSFH-8	21.1	136.6	59.4	58.2	2973	32.83	43.3	19.2
MSFH-51	19.8	128.7	56.3	55.6	2679	31.82	40.5	18.5
MSFH-999	20.6	132.6	57.7	55.9	2852	31.96	43.2	19.0
GK-2004	19.5	122.6	51.1	53.0	2241	31.53	39.5	17.2
No. 6460	19.8	127.6	55.9	54.9	2432	31.73	40.7	17.3
No. 3301	21.2	130.9	57.9	55.1	2622	32.60	42.3	18.8
CD (P=0.05)	1.2	4.3	1.9	1.9	125	3.31	2.0	0.6

It is therefore, concluded that hybrid MSFH-8 and NSFH-999 may be grown for realizing higher seed, oil and protein yields during spring season in Mollisols of Uttaranchal. Hybrid Sungene-85 had higher oil and protein content than Morden, though both had same maturity period and 5 days earlier than other cultivars. Therefore, Sungene-85 may be preferred over Morden to fit into different cropping systems.

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Short communication

Effect of sulphur on the yield and oil content of rice fallow sunflower, *Helianthus annuus* L.

M. Ganapathy and N. Ramesh and G. Baradhan

Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar-608 002, TN

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Sunflower, *Helianthus annuus* L. in recent years gained importance owing to the richness of polyunsaturated fatty acids (PUFA) in its oil. Nitrogen and sulphur requirement of sunflower is quite high. Application of 30 kg S/ha along with nitrogen resulted in significant increase in seed yield compared to nitrogen alone (Rathore *et al.*, 2001). However, response of sunflower to sulphur varies with soil type, season and cropping sequence. Sulphur is indispensable for the synthesis of essential oils and it plays a vital role in chlorophyll formation (Kene *et al.*, 1999). Information on the requirement of sulphur for sunflower as a rice fallow crop is meagre. Hence, the present investigation was carried out to study the effect of different source and levels of sulphur on sunflower. The field experiment was conducted during 2000-01, at the Experimental Farm, Faculty of Agriculture, Annamalai University, Tamil Nadu. The soil of the experimental site was clay with low in available N (222 kg/ha), medium in available P (18.5 kg/ha) high in available K (380 kg/ha) and low in sulphur (9.8 kg/ha). The experiment was laid out in Randomized Block Design with three replications and 9 treatments (Table 1). The sunflower cultivar Morden was sown with a recommended doses of 60, 90 and 60 kg of N, P and K/ha in the form of Urea, SSP and Muriate of Potash. All the other cultural practices were adopted as per the recommended package of practices.

Table 1 Effect of sulphur on the yield and oil content of rice fallow sunflower

	Treatment	Height (cm)	Head diameter (cm)	100 seed weight (g)	Yield (kg/ha)	Oil content
T_1	Control	141	14.0	4.6	1451	34.4
T_2	20 kg S/ha (AS)	144	14.4	4.7	1655	35.5
T_3	20 kg S/ha (SSP)	144	14.5	4.7	1695	35.5
T_4	20 kg S/ha (Gypsum)	142	14.0	4.7	1622	35.6
T_5	20 kg S/ha (Elemental S)	143	13.9	4.6	1619	35.5
T_6	40 kg S/ha (AS)	147	14.9	4.8	1791	36.2
T_7	40 kg S/ha (SSP)	147	14.8	4.9	1789	36.2
T_8	40 kg S/ha (Gypsum)	145	14.4	4.9	1754	36.2
T_9	40 kg S/ha (Elemental S)	145	14.6	4.8	1741	36.1
	SEm±	2	0.3	0.1	58	0.4
	CD (P=0.05)	3	0.6	0.1	122	0.8

Application of sulphur significantly increased the plant height and head diameter. The highest plant height was recorded with the application of 40 kg S/ha (Ammonium Sulphate) and 40 kg S/ha (SSP) compared to the other treatments and it was on par with 40 kg S/ha (Elemental Sulphur). Reddi Ramu and Maheswari Reddy (2003) reported that sunflower responded to the application of 40 kg S/ha, by recording a higher plant height. Application of 40 kg S/ha (Ammonium Sulphate) recorded a significantly highest head diameter and it was on par with 40 kg S/ha (Single Super Phosphate). A similar results was also reported by Legha and Gajendara (1999) and Ajai Singh et al. (2000). Influence of sulphur also significantly increased the 100 seed weight. Treatments 40 kg S/ha (SSP) and 40 kg S/ha (Gypsum) recorded the highest value, being significantly higher than all other treatments. Similar results were reported by Krishnamurthy and Mathan (1999). Availability of more photosynthates due to sulphur application has resulted in increased test weight. The seed yield recorded in 40 kg S/ha (Ammonium Sulphate) was highest to a tune of (1791 kg/ha) compared to the other treatments. The treatments 40 kg S/ha (SSP), 40 kg S/ha (Gypsum) and 40 kg S/ha (Elemental Sulphur) were on par. Similar results were reported by Krishnamurthi and Mathan (1999) and Reddi Ramu and Maheswara Reddy (2003). Increased seed yield is due to the combined effects of increase in head diameter and filled seeds/head which was due to increased translocation of photosynthates.

Therefore, application of sulphur @ 40 kg/ha through various sources resulted in increased seed yield and oil content in the rice fallow sunflower.

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Short communication

Response of summer sesame, *Sesamum indicum* L. to varying levels of nitrogen and sulphur under irrigated condition

B. Duary and S. Mandal

AICRP on Weed Control, Institute of Agriculture, Visva-Bharati, Sriniketan-731 236, WB

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Sesame (*Sesamum indicum* L.) is one of the most ancient oilseed crops of India. The crop is cultivated almost throughout India for its high quality oil and it has tremendous potential for export. It ranks third in terms of total oilseed area and fourth in terms of total oilseed production in the country. Sesame occupies a position of prominence in the oilseed scenario of the state of West Bengal. It ranks second in area and production next only to rapeseed-mustard in the State. This is predominantly grown during summer season after harvest of potato, *kharif* rice and mustard. The area coverage in summer is around 93% of the total area under sesame in the State. In the cropping system of this State summer sesame is mostly grown either after harvest of potato without any fertilizer or after the harvest of *aman* paddy. Among various factors responsible for the low productivity levels of sesame, its cultivation in marginal soils having poor soil fertility without fertiliser application is the most important one. Both nitrogen and sulphur are vital constituents of plant protein. Nitrogen is the essential plant nutrient for chlorophyll formation also. Increased seed yield of sesame with increasing levels of N was reported by Patel and Mishra (2000), Deshmukh *et al.* (1990) and Moorthy *et al.*(1997). Sulphur can be identified as a key element for increasing the production of oilseeds, of course in combination with NPK (DOR, 1984; 1985). Sulphur is required for the synthesis of proteins and oils (Tomar *et al.*, 1997; Sharma and Jalal, 2001). The present experiment was conducted to study the response of summer sesame to varying levels of nitrogen and sulphur.

A field experiment was conducted during the summer season of 1999 and 2000 at Pulses and Oilseeds Research Sub-Station (PORSS), Beldanga, Murshidabad, West Bengal. The soil was sandy loam with pH 7.4, organic carbon 0.33 %, available N 380 kg/ha, available P_2O_5 56 kg/ha, available K_2O 99 kg/ha and sulphur 19.2 kg/ha respectively. The experiment was laid down in randomised block design with 3 replications. The treatments comprised of combinations of four levels of sulphur (0, 20, 40 and 60 kg/ha) and four levels of nitrogen (20, 40, 60 and 80 kg/ha). Plot size for each treatment was 4m x 3m. The fertilisers P_2O_5 and K_2O @ 40 kg/ha each were uniformly applied in all the treatments. Nitrogen and phosphatic fertilisers were applied through urea and diammonium phosphate. Potassic fertiliser was applied through muriate of potash. Sulphur was applied through gypsum as per treatment. The crop was sown in the month of March with optimum soil moisture obtained through a pre-sowing irrigation to ensure good germination during both the years. The variety Tilottoma (B-67) was sown with the spacing of 30 cm x 10 cm. The crop received three irrigations at 30, 45 and 65 DAS along with one pre-sowing irrigation during both the years. Crops were harvested at 84 DAS in 1999 and 85 DAS in 2000. The observations on growth of the crop were recorded at the time of harvesting. After harvesting the seed yield recorded per plot were converted to yield/ha and used to workout other yield parameters by using standard procedure. The economics were calculated using the current cost of inputs and market price of seed and stick of sesame.

Growth of sesame: The perusal of the data (Table 1) indicated that varying levels of nitrogen had significant influence on plant height (cm) of sesame during both the years. The height was increased sharply from 123.1 to 130.3 cm and 95 to 100.9 cm due to increment of N levels from 20 to 80 kg/ha during both the years respectively. On the other hand application of 40 kg S/ha produced maximum plant height during both the years. After that plant height was decreased at 60 kg S/ha. Number of branches also increased with increasing levels of N from 20 to 60 kg/ha both the year. But the effect of sulphur was not significant.

Yield components: The yield component of sesame like number of capsule / plant, number of seeds /capsule and test weight varied significantly due to varying levels of N application (Table 1) Though application of 80 kg N /ha produced the best results in different yield component, the effect of 60 kg N/ha was found at par. Again, application of 40 and 60 kg N/ha produced at par effect on all the yield components of sesame in both the years. Desmukh *et al.* (1990), found that the response of test weight to N was significant up to 120 kg/ha whereas number of capsules/plant and weight of grain responded up to 80 kg N/ha.

Sulphur application significantly increased all the yield components of sesame over control during both the years (Table 1). Maximum number of capsules/ plant, seeds/ capsules, 1000 seed weight of sesame was produced by 40 kg S/ha during both the years.

The interaction effect of nitrogen and sulphur levels was found significant in producing number of capsules/plant in both the years. But no interaction effect was observed on number of seeds/ capsule and 1000 seed weight of sesame.

Seed yield: Both the nitrogen and sulphur levels had significant effect on seed yield of sesame. Seed yield increased sharply from 1002 kg/ha to 1164 kg/ha and 974 kg/ha to 1166 kg /ha due to gradual increment of nitrogen levels from 20 kg to 80 kg N/ha during both the years respectively. However the yield at 80 kg/ha was at par with 40 and 60 kg/ha. The pooled data over two years revealed that 80 kg N/ha produced the highest yield and it was at par with 60 kg N/ha. The earlier result reported by Chatterjee *et al.* (1992) revealed that the economic optimum dose of the variety B-67 under irrigated condition was only 50 kg/ha for medium fertility situation. Thus the lower response of the variety to nitrogen level might be due to the fact that the initial nitrogen status of the experimental field was medium and the preceding crop was grain legume, blackgram. The higher seed yield might be due to enhanced number of branches and yield attributes *viz.*, number of capsules/plant and test weight with increased level of nitrogen. Similar results of higher seed yield of sesame due to enhanced yield attribute were explained by Patel (2000) and Patel and Mishra (2000).

Seed yield of sesame increased significantly due to different levels of sulphur application during both the years. Among the sulphur levels 40 kg S/ha produced the highest yield of sesame (1248, 1179 and 1209 kg/ha) in the 1st year, 2nd year and pooled over two years respectively. From the pooled data of two years (Table 1 and 2) it revealed that application of sulphur @ 20 and 40 kg/ha recorded 9% and 20% more yield respectively over control indicating higher requirement of this element by sesame. Similar result of economic yield response was achieved at application of 40 kg S/ha (Chatterjee *et al.*, 1992). Though the sharp yield increment was observed from 0 to 40 kg S/ha, it was reduced at 60 kg S/ha. Further it was also noticed that application of 20 and 60 kg S/ha produced at par effect in both the years and pooled over two years. This was in agreement with other workers (Mailer, 1989; Narwal *et al.*, 1991; Saha and Mandal, 2000).

Table-1 Effect of nitrogen and sulphur on growth, yield component and seed yield of sesame

Treatment	Plant height (cm)		No. of branches/plant		No. of capsules/plant		No. of seeds/capsule		1000 seed weight (g)		Seed yield (kg/ha)		
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	Pooled
Nitrogen levels (N kg/ha)													
20	123.1	95.0	2.5	3.8	21	44	35	42	2.99	2.85	1002	974	988.0
40	126.8	96.5	3.6	4.3	30	51	38	45	3.13	2.83	1093	1114	1103.3
60	126.8	99.3	4.9	5.2	33	55	39	47	3.21	2.93	1136	1163	1149.5
80	130.3	100.9	4.0	4.2	34	56	40	48	3.24	3.02	1164	1166	1165.0
CD (P=0.05)	4.25	3.47	1.0	1.1	2.8	5.0	2.1	2.4	0.17	0.16	96.98	63.02	39.26
Sulphur levels (S kg/ha)													
0	125.4	97.8	2.4	3.8	29	47	32	41	3.00	2.88	983	1026	1004.5
20	128.1	98.3	2.8	4.0	32	51	37	45	3.14	2.96	1086	1102	1094.0
40	129.1	98.3	2.7	3.8	34	55	42	49	3.25	3.09	1248	1170	1209.5
60	124.2	98.2	2.8	4.2	32	53	40	47	3.18	2.98	1078	1118	1098.0
CD (P=0.05)	4.25	NS	NS	NS	2.3	3.8	2.1	2.4	0.17	0.16	96.98	63.02	39.26
N x S interaction													
CD (P=0.05)	NS	NS	NS	NS	5.7	10.0	NS	NS	NS	NS	193.96	123.23	34.0

Table 2 Interaction effect of nitrogen and sulphur on seed yield (kg/ha) of sesame

Treatment	1999					2000					Pooled				
	N_{20}	N_{40}	N_{60}	N_{80}	Mean	N_{20}	N_{40}	N_{60}	N_{80}	Mean	N_{20}	N_{40}	N_{60}	N_{80}	Mean
S_0	873	924	1083	1051	983	853	1027	1115	1110	1026	863	976	1099	1081	1005
S_{20}	947	963	1234	1199	1086	968	1055	1169	1217	1102	958	1009	1202	1208	1094
S_{40}	1120	1312	1287	1275	1248	1010	1245	1232	1192	1170	1065	1279	1260	1234	1210
S_{60}	1067	1171	940	1132	1078	1065	1127	1136	1144	1118	1066	1149	1038	1138	1098
Mean	1002	1093	1136	1164	-	974	1114	1163	1166	-	988	1103	1150	1165	-

	CD (P=0.05)	CD (P=0.05)	CD (P=0.05)
Nitrogen	96.98	63.02	39.26
Sulphur	96.98	63.02	39.26
N x S interaction	193.96	126.23	34.00

The interaction between N and S is generally positive. Nitrogen and sulphur enhance the efficiency of one another (Tandon, 1991). The interaction effect of nitrogen and sulphur levels was significant on seed yield of sesame during both the years and in pooled analysis (Table 2). From the result it was observed that application of 40 kg N and 40 Kg S/ha produced the highest (1312 and 1245 kg/ha) yield of sesame during both the years respectively and it was closely followed by $N_{60}S_{40}$ and $N_{80}S_{40}$ treatments. Such response may be explained by the fact that the sulphur status of the soil was low and the nitrogen status was comparatively higher and the preceding crop was grain legume, which also requires high quantity of sulphur. From the pooled analysis it was observed that application of $N_{40}S_{40}$ produced the highest seed yield (1279 kg/ha) of sesame and it was at par with the interaction effect of $N_{60}S_{40}$ (1260 kg/ha) and $N_{80}S_{40}$ (1234 kg/ha) treatments.

Economics: Highest gross return, net return as well as benefit cost ratio (Table 3) were obtained with the combined application of N and S each at 40 kg/ha.

Thus it may be concluded that a combination of 40 kg N/ha and 40 kg S/ha along with recommended P and K under *irrigated condition should be applied in sesame crop for* obtaining higher seed yield.

Table 3 Economics of sesame cultivation under varying levels of nitrogen and sulphur (on pooled data)

Treatments	Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	Benefit : cost ratio
$N_{20}S_0$	11580	14145	2565	1.22
$N_{20}S_{20}$	12135	15720	3585	1.29
$N_{20}S_{40}$	12690	17475	4785	1.37
$N_{20}S_{60}$	13245	17540	4295	1.32
$N_{40}S_0$	11823	16040	4217	1.35
$N_{40}S_{20}$	12378	16635	4257	1.34
$N_{40}S_{40}$	12933	20885	7952	1.61
$N_{40}S_{60}$	13488	18985	5497	1.40
$N_{60}S_0$	12065	17985	5920	1.49
$N_{60}S_{20}$	12620	19780	7160	1.56
$N_{60}S_{40}$	13175	20700	7525	1.57
$N_{60}S_{60}$	13730	18720	4990	1.36
$N_{80}S_0$	12306	17765	5459	1.44
$N_{80}S_{20}$	12861	19870	7009	1.54
$N_{80}S_{40}$	13416	20260	6844	1.51
$N_{80}S_{60}$	*13971*	*18720*	*4749*	*1.33*

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Short communication

On-farm assessment of variety and castor cake for optimizing mustard, *Brassica juncea* (L.) Czern & Coss yield under rainfed saline conditions

M.K. Patel, H.C. Pathak, K.J. Desai, A.D. Raj and C.V. Raghavaiah*

Main Castor-Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar-385 506, Gujarat

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Mustard is one of the important *rabi* oilseed crops of Gujarat in general and North Gujarat in particular. The agroclimatic condition of North Gujarat is the most ideal for mustard cultivation. The crop is grown in about 3.5 lakh ha of area with about 5.0 lakh tonnes of production and average productivity of about 1400 kg/ha, which is one of the highest in the country. In some parts of Mehsana, Banaskantha and Patan districts of North Gujarat; North Rajkot and Jamanagar in Saurashtra the crop is grown under conserved moisture where salinity is one of the major production constrains. The salinity adversely affects the germination, emergence, and important growth characters leading to drastic reduction in yield (Kumar and Singh, 1980). The management of salinity under such fragile ecosystem will help increase the productivity of this important edible oilseed crop which has tremendous potential to meet the ever increasing oilseed demand of the country.

Therefore, an experiment was planned to demonstrate the proven management technology for optimization of mustard yield through identified resistant varieties and castor cake as source of organic matter. The experiment was conducted at two locations i.e., Motichandur and Kanij villages of Patan district on farmer's fields. The texture of the soil was clayey at both the locations, Ece 6.70 ds/m, pH 8.50, low available N, P and medium K at Motichandur and Ece 8.70 and pH 8.20 with low in available N medium in P and high in Potash content at Kanij. Both the locations had predominant soluble salts and exchangeable salts of Na^+, Cl^-, Ca^{++}, Mg^{++} and HCO_3^-. During monsoon, the total rainfall was 452 mm. There was no rainfall after sowing of the experiment.

At both the locations, three mustard varieties i.e., GM-2, Varuna and Bio-902 identified as salt tolerant were sown with (1 t/ha) and without castor cake. Each treatment was sown in 243 m^2 area, following a spacing of 45 cm between row. Before sowing of the crop, the soil was frequently harrowed to conserve moisture. During last harrowing, castor cake was applied as per treatment. The fertilizer was drilled at 25-25-0 $N:P_2O_5:K_2O$ kg/ha before seeding. Necessary plant protection measures were taken during crop period. The observation on germination, days to 50% flowering, yield contributing characters, seed yield, test weight and oil content were recorded. Application of castor cake improved the germination (%) and induced earlier flowering in all genotypes as compared to that without castor cake (Table 1).

Table 1 Effect of castor cake on yield and yield contributing characters of mustard genotypes

Location	Variety and treatment	Germination (%)	No. of branches		No. of siliqua		Length of siliqua (cm)	Seeds/ siliqua	Yield/ha (kg)	1000 seeds weight (g)	Oil content (%)	% increase in yield
			Primary	Secondary	Primary	Secondary						
Kanij	Varuna + without castor cake	59	7	17	30	201	4.6	13	1100	5.2	37.2	13.6
	Varuna + castor cake	69	9	23	44	237	5.3	15	1250	5.7	38.3	-
	GM-2 + without castor cake	58	5	16	30	190	5.0	11	1060	5.1	37.6	11.3
	GM-2 + castor cake	65	9	20	40	293	6.0	15	1180	5.1	39.4	-
	Bio-902 + without castor cake	60	6	15	32	210	4.6	13	1210	4.9	38.2	14.5
	Bio-902 + castor cake	72	9	22	46	292	6.2	17	1385	5.9	38.5	-
Moti-chandur	Varuna + without castor cake	58	6	15	27	185	4.3	12	920	5.1	37.2	14.1
	Varuna + castor cake	70	8	20	41	225	5.0	14	1050	5.6	38.3	-
	GM-2 + without castor cake	54	7	13	24	190	5.0	10	840	5.0	38.4	13.1
	GM-2 + castor cake	60	9	18	37	280	5.8	13	950	5.1	39.2	-
	Bio-902 + without castor cake	58	6	17	36	202	4.3	12	1000	4.9	38.1	15.0
	Bio-902 + castor cake	70	8	21	45	285	6.0	16	1150	5.9	38.4	-

* Principal Scientist (Agronomy), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP.

The maximum germination was noted in Bio-902 followed by Varuna at both the locations. The application of castor cake in all the varieties resulted in higher values for yield contributing characters, seed yield and oil content. The average seed yield of two centers indicated that application of castor cake at 1 t/ha recorded higher seed yield in all the varieties. The increase was 13.6, 11.3 and 14.50 % in Varuna, GM-2 and Bio-902, respectively. On an average the oil content was increased from 37.2 to 38.3, 38.1 to 39.4 and 38.1 to 38.4 in Varuna, GM-2 and Bio-902, respectively by the application of castor cake. Average test weight was increased from 5.2 to 5.7, 5.1 to 5.1 and 4.9 to 5.9 g in Varuna, GM-2 and Bio-902, respectively by the application of castor cake.

It was concluded that the application of castor cake at 1 t/ha and adoption of mustard variety, Bio-902 or Varuna greatly improved the yield of mustard under conserved moisture situation where salinity is a problem. Kumar and Malik (1983) also reported that the mustard variety Varuna was rated as salt tolerant.

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Short communication

Soil moisture studies in different soybean, *Glycine max* (L.) Merrill. genotypes in relation to land configuration treatments[1]

D.M. Lomte, M.G. Umate, N.V. Kagade and S.P. Kausale

Marathwada Agricultural University, Parbhani, Maharashtra

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Soybean [*Glycine max* (L.) Merrill] has emerged as an important oilseed crop in Maharashtra state. It is generally grown under rainfed conditions in Marathwada and Vidarbha region of Maharashtra. Due to erratic distribution of rainfall, the crop experiences moisture stress during the dry spell at one or other growth stages, results in significant reduction in the yield. These yield losses are expected at higher level especially in early genotypes with determinate types.

The loss in yield can be avoided or minimized if good amount of water is stored in the soil during rainy days and utilized by the crop during moisture stress or dry spell. Studies on soil and water management for increasing crop production revealed that modification of land configuration such as ridges and furrows for soybean in vertisol was superior over flat bed and recommended in water shed development (Gupta *et al.*, 1984). In the present study, the crop was subjected to different land layouts by opening of furrows at different intervals which will certainly facilitate higher infiltration of water and thereby increasing total water storage.

A field experiment was carried out at the experimental farm of Dryland Agriculture Research Centre, MAU, Parbhani. The trial consisted of three genotypes *viz.*, Prasad, JS-335, MAUS-47 and three land configuration *viz.*, opening of furrow after every 3rd row (L_1), opening of furrow after every 6th row (L_2) and flat bed (L_3) laid out in Randomized Block Design (Factorial) with three replications during *kharif*, 1999. Sowing was done by dibbling at 45 x 05 cm distance. Furrows were opened at 25 days after sowing. All recommended practices were followed for growing the soybean crop.

Moisture content: The moisture content in soil at seedling stage was highest followed by at harvest (Table 1). Whereas lowest moisture content was observed during dry spell i.e., 60 days after sowing ((DAS). Moisture content in 15-30 cm soil layer was comparatively higher than 0-15 cm soil layer at all growth stages. Opening of furrow after every 3rd row (L_1) recorded highest moisture content followed by opening of furrow after every 6th row (L_2). Whereas, lowest moisture content was recorded in flat bed (L_3). In all land configuration treatments including flat bed, at lower depth (15-30 cm) moisture content was higher than upper layer (0-15 cm).

Moisture use: Soybean variety Prasad recorded highest moisture use of 392.33 mm followed by MAUS-47 and JS-335 (Table 2).

Table 1 Moisture content (%) in different land configuration at various growth stages of soybean

Stage	Depth (cm)	Land configuration		
		L_1	L_2	L_3
Seedling stage	0-15	31.32	30.04	29.27
	15-30	34.41	43.10	31.35
60 days after sowing	0-15	23.34	21.43	19.13
	15-30	25.87	22.92	20.59
At harvest	0-15	24.03	22.22	20.73
	15-30	25.78	24.53	23.13

L_1 : Opening of furrow after every 3rd row; L_2 : Furrow after every 6th row and L_3 : Flat bed

[1] Part of M.Sc. (Ag.) Thesis submitted to Marathwada Agricultural University, Parbhani, Maharashtra by the first author.

Table 2 Moisture use (mm) and moisture use efficiency (kg/mm/ha) from 0-30 cm depth as affected by different treatments

Treatment	Land configuration			
	L_1	L_2	L_3	Mean
Genotype	***Moisture use (mm)***			
MAUS-32 (Prasad)	398	394	385	392.33
JS-335	391	382	378	383.66
MAUS-47 (Parhani sona)	394	389	382	388.33
Mean	394.33	388.33	381.33	381.66
	Moisture use efficiency (kg/mm/ha)			
MAUS-32 (Prasad)	9.54	8.74	8.38	8.88
JS-335	8.97	8.80	8.69	8.82
MAUS-47 (Parbhani sona)	7.50	7.17	7.11	7.26
Mean	8.67	8.23	8.23	8.06

Among land configuration treatments, treatment L_1 utilized maximum soil moisture (394.33 mm) followed by L_2 (388.33 mm) and lowest in L_3 (381.66 mm). The trend of moisture use within the genotypes was just similar to that of general trend of moisture use.

Moisture use efficiency: Genotype, Prasad recorded highest moisture use efficiency (8.88 kg/mm/ha) followed by JS-335 (8.82 kg/mm/ha) and MAUS-47 (7.26 kg/mm/ha). Moisture use efficiency was highest in land configuration treatment L_1 followed by L_2 and L_3 (Table 2).

Patil *et al.* (1981) reported that tied ridges were more effective in conserving soil water. Moisture studies in soybean revealed that for efficient utilization of soil moisture, selection of Prasad and JS-335 with land configuration treatment, opening of furrow after every 3rd row, 25 days after sowing was found most optimum.

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Short communication

Effect of nutrient management and moisture conservation practices on yield and economics of sunflower, *Helianthus annuus* L. cultivars in Alfisols of semi-arid tropics

G. Pratibha, G.R. Korwar, K.L. Sharma and B.N. Reddy*

Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad-500 059, AP

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Sunflower is an important oilseed crop of India, and the crop is generally cultivated as a rainfed crop in rainy season. Sunflower is more drought tolerant crop with a deep explorative root system (Connar and Sadras, 1992). It has better capacity to extract moisture from deeper soil horizons compared to below zones of normal small grain crops (Merrill *et al.*, 1994).

Moisture and nutrients have been identified as critical components in enhancing the productivity of Sunflower (Reddy *et al.*, 2003). In semi arid tropical regions, crop experiences moisture stress intermittently due to uneven distribution of rainfall leading to substantial decrease in productivity. The reduction in yield depends on the duration of stress and stage of crop growth period. The productivity of the sunflower can be enhanced by selecting a variety exhibiting intrinsic tolerance to moisture and nutrient stress that show least reduction in yield under stress situation.

Rainfed Alfisols are generally degraded with poor native fertility and have serious limitations of soil depth leading to low water storage capacity (Vittal *et al.*, 1990). Further, the yield advantage of the crops depends on total rainfall duration and intensity of the dry spells. The soil depth and soil moisture are the critical factors influencing the production potential. The low effective soil depth affects the phenological and morphological expressions of crop due to soil moisture limitation. The soil moisture conservation may provide sufficient soil water storage to produce economic yield of sunflower. Sunflower responds to application of fertilizer under rainfed conditions. The farmers of this area are poor and have low investment capacity. The identification of suitable variety for nutrient and moisture stress conditions is important to enhance the productivity of sunflower. This necessitated an on farm trial to evaluate the Cultivars for nutrient and moisture constraint conditions.

On farm trials were conducted during 2000-01 in Alfisols of Mahaboobnagar district of Andhra Pradesh to identify the cultivars for moisture and nutrient stress conditions and techno economic feasibility. The experiment was conducted in five villages *viz.*, Chityal, Auchutapuram, Ankur, Venkatapuram and Chimanaguntapalli in 36 farmers fields representing different depths of soil.

Texturally, the experimental soils varied from sandy loam to sandy clay loam. The site characteristics of experimental soils are presented in Table 1. The experiment was laid out in spilt split plot design with soil depths and moisture conservation practice as main plots, fertilizers and varieties were taken as sub and sub-sub plot treatments respectively.

The soils with 8±4.3 cm effective depth were assumed as shallow and soils with 15 ± 4.5 cm effective depths were considered as deep soil respectively.

The recommended moisture conservation treatments consisted of deep tillage and furrows opened after every two rows of sunflower at 20-25 days after sowing (M_1). While farmers practice comprised of shallow ploughing and inter cultivation (M_0). Farmer's method of fertilizer dose includes no fertilizer (F_0) where as, recommended dose includes 60:30 Kg N and P_2O_5 kg/ha (F_1). The sunflower hybrids tested against local check variety Morden were KBSH-1, APSH-11 and MSFH-17. The sunflower crop was sown in first week of August at a spacing of 60x 30 cm. The crop experienced a dry spell of 13 days each during vegetative and flowering stage. After the harvest of crops, yields were recorded.

The oil content was estimated by using Nuclear Magnetic Resonance (NMR) instrument. The economics of different treatments was calculated based on the prevailing market prices.

The crop experienced two dry spells of 13 days each during vegetative and flowering stage, the yield levels of the experiment were satisfactory.

Soil types : Depth of soil significantly influenced the seed, stalk yields and harvest index (Table 2), Deep soil recorded 63% higher seed yield (852 Kg/ha) as compared to shallow soil. The substantial increase in yield in deep soils is

* Principal Scientist (Agronomy), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP.

attributed to the better moisture storage and nutrient content compared to shallow soil. This might have helped in improvement of growth and yield attributes. The depth of soil did not influence the oil content significantly. However, deep soil recorded significantly higher oil yield over shallow soil. This was obviously due to increase in seed yield. The rainfall use efficiency increased with the depth of soil. Deep soil recorded 3.86 kg/mm/ha of rainfall use efficiency as against 2.36 kg/mm/ha in shallow soil (Table 3).

Table 1 Site characterization

Item	Soil depth							
	Shallow				Medium deep			
	Available phosphorus				Available phosphorus			
	Low	Mean	Medium	Mean	Low	Mean	Medium	Mean
Chemical								
O.C (%)	0.278-0.316	0.297	0.305-0.379	0.342	0.350-0.382	0.366	0.297-0.401	0.349
Total nitrogen (%)	0.072-0.089	0.081	0.077-0.1	0.088	0.077-0.084	0.080	0.080-0.093	0.086
Available phosphorus (kg/ha)	10.7-11.6	11.15	19.7-20.5	20.1	10.6-12.5	11.5	20.1-22.3	21.2
Available potassium (kg/ha)	145.9-183.5	164.7	181.7-203.4	192.5	151.4-257.3	204.3	169.4-278.5	223.9
Physical	Soil depth							
	Shallow				Medium deep			
Texture	Sandy loam to sandy clay loam				Sandy loam to sandy clay loam			
Moisture at FC* (%)	7.5% to 11%				13.72% to 16.73%			

* *FC = Field capacity*

Moisture conservation: Recommended moisture conservation practice recorded significantly higher seed yield than the farmers practice (Table 3). The increase in seed yield in recommended method of moisture conservation over farmers method was to the tune of 22.1%. The increase in yield is attributed to availability of more moisture, which in turn helps in better utilization of applied nutrients resulting in improvement of attributing characters like number of filled seeds and % filled seeds. However, the test weight was not influenced by the moisture conservation. Similar observations were earlier made by Baby and Bapi Reddy (1997). The moisture conservation treatments recorded higher harvest index (HI) when compared to no moisture conservation.

Significant improvement in oil content and oil yield was observed due to moisture conservation over no moisture conservation treatment. The improvement in seed yield may be due to better availability of moisture in conservation treatment. The increased oil yield under recommended moisture conservation was also due to increase in oil content as well as seed yield. Recommended moisture conservation method recorded 56% higher rainfall use efficiency.

Fertilizer: Application of recommended dose of fertilizer significantly increased the yield (889 kg/ha) over no fertilizer application .The increase in yield was 85% with fertilizer application when compared to no fertilizer application. The improvement in yield might be ascribed to improvement in vigour and yield attributes due to better nutrient availability. Higher harvest index and stalk yield were also recorded with fertilizer application. Oil yield was significantly influenced by fertilizer application The increased oil yield was also due to increase in oil content as well as seed yield. The increase in rainfall use efficiency by using fertilizer was 84%.

Cultivars: Variation in yields of cultivars was observed and reflected in seed yields (Fereres et al., 1986). Among the Cultivars, KBSH-1 and MSFH-17 performed better than the Morden and APSH-11. Both KBSH-1 and MSFH-17 Cultivars recorded higher seed yield over the check variety. The increase in seed yields of various Cultivars is mainly due to increase in growth and yield components such as head diameter, filled grain and % seed filling. However, test weight was not influenced by the cultivars. The medium duration hybrids found superior to short duration variety Morden. The variation in rooting depth and moisture extraction pattern was observed in Sunflower Cultivars. The increase in rooting depth might have helped in absorbing more moisture and achieving better growth and yield of KBSH-1 and MSFH-17 compared to Morden. The variation in rainfall use efficiency observed in different Cultivars was 3.07, 3.88, 2.32 and 3.2 kg/mm/ha with Morden KBSH-1, APSH-11 and MSFH-17, respectively.

Table 2 Influence of different treatments on yield attributing characters of sunflower

Treatment	*Head diameter (cm)*	*No. of filled grains/head*	*% filled grains*	*1000 seed weight (g)*
Soil type				
Deep soil	15.2	616	51.77	45.95
Shallow soil	13.8	461	38.00	45.35
SEm±	0.134	7.680	0.450	0.613
CD (P=0.05)	0.602	34.54	2.025	NS
Moisture conservation				
M_1	14.5	560	47.86	47.03
M_0	14.4	498	41.91	43.26
SEm±	0.134	7.680	0.450	0.613
CD (P=0.05)	NS	34.54	5.03	NS
Fertilizers				
F_0	11.8	501	41.27	38.00
F_1	17.2	577	48.51	52.04
SEm±	0.061	4.760	0.474	0.416
CD (P=0.05)	0.177	13.78	1.374	1.21
Varieties				
Morden	13.2	417	34.61	49.95
KBSH-1	15.5	762	63.24	39.46
APSH-11	13.7	431	35.79	42.24
MSFH-17	15.3	546	45.89	48.94
SEm±	0.086	9.510	0.670	0.588
CD (P=0.05)	0.25	27.57	1.943	1.703
Interaction				
S x T	NS	NS	NS	NS
F x V	Sig	Sig	NS	Sig
S x F	NS	NS	NS	NS
S x V	Sig	NS	Sig	NS
S x F x V	Sig	NS	NS	NS
T x F	Sig	NS	NS	Sig
T x V	Sig	NS	NS	NS
T x F x V	Sig	NS	NS	NS
S x T x F	Sig	NS	NS	NS
S x T x V	Sig	NS	NS	NS
S x T x F x V	Sig	Sig	NS	NS

Table 3 Influence of different treatments on yield and yield attributing characters of sunflower

Treatment	Seed yield (kg/ha)	Stalk yield (kg/ha)	Harvest index (%)	Oil content (%)	Oil yield (kg/ha)	Rainfall use efficiency (kg/mm/ha)
Soil type						
Deep soil	852	950	47.80	35.52	307	3.88
Shallow soil	521	794	40.67	34.67	184	2.36
SEm±	8.9	14.1	0.237	0.205	3.0	
CD (P=0.05)	30.7	48.9	0.819	NS	10.5	
Moisture conservation						
M_1	755	894	45.28	36.09	276	3.43
M_0	618	850	43.18	34.10	216	2.19
SEm±	8.8	14.1	0.237	0.205	3.1	
CD (P=0.05)	30.7	48.9	0.819	0.923	10.7	
Fertilizers						
F_0	848	635	42.88	34.55	170	219
F_1	889	1108	45.58	35.64	322	4.04
SEm±	11.3	22.7	0.288	0.265	4.3	
CD (P=0.05)	32.2	64.2	0.814	0.768	12.3	
Varieties						
Morden	537	942	36.07	31.92	174	3.07
KBSH-1	912	978	50.84	38.26	350	3.88
APSH-11	546	852	39.62	34.41	197	2.32
MSFH-17	752	714	50.42	35.80	262	3.2
SEm±	16.1	32.1	0.407	0.375	6.2	
CD (P=0.05)	45.5	90.8	1.151	1.086	17.3	

	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)
S x T	12.56	43.48	19.98	69.18	0.335	1.159	0.290	1.306	4.36	15.07
F x V	22.70	64.41	45.42	128.50	0.575	1.628	0.530	1.536	8.67	24.51
S x F	16.10	45.54	32.12	90.84	0.407	1.151	0.375	NS	6.13	17.33
S x V	22.70	64.41	45.42	NS	0.575	1.628	0.530	1.536	8.67	24.51
S x F x V	32.21	NS	64.24	NS	0.814	2.302	0.749	NS	2.26	NS
T x F	16.10	NS	32.12	90.84	0.407	1.151	0.375	NS	6.13	NS
T x V	22.77	NS	45.42	128.50	0.575	1.628	0.530	NS	8.67	NS
T x F x V	32.21	NS	64.23	181.70	0.814	2.302	0.749	2.172	12.30	34.67
S x T x F	22.77	NS	45.42	128.80	0.575	NS	0.530	NS	8.67	NS
S x T x V	32.21	91.09	64.23	NS	0.814	2.302	0.749	2.712	12.30	NS
S x T x F x V	45.54	NS	90.84	256.90	1.151	3.255	1.060	NS	17.30	NS

Table 4 **Influence of the different treatments on monitory returns and B:C ratio**

Treatments	Cost of cultivation (Rs/ha)	Net monetary returns (Rs/ha)	Add cost of cultivation (Rs/ha)	Add net returns (Rs/ha)	Add B:C ratio
Deep soil	5003	8237	-	5175	-
Shallow soil	5003	3062	-	-	-
M1	5230	6816	560	1642	2.93
M0	4669	5174	-	-	-
F1	5402	8394	828	5460	6.59
F0	4573	2934	-	-	-
Morden	4695	3368	-	-	-
KBSH-1	4952	8433	257	5065	19.7
APSH-11	5252	7173	557	3805	6.83
MSFH-17	5052	3683	357	315	0.88

M_1 = Deep tillage; M_0 = Shallow tillage;
F_1 = Recommended fertilizers; F_0 = No. fertilizers

Interactions: The significant interaction effects in seed yields were observed for soil type Moisture conservation, Fertilisers cultivars, soil type fertilizers soil type and cultivars In shallow soil, moisture conservation recorded higher harvest index. Morden recorded higher harvest index in moisture conservation treatment. Whereas, KBSH-1 recorded higher harvest index compared to the other varieties under constraint conditions. The harvest index was relatively higher for Morden and MSFH-17 under better conditions. This shows that partitioning efficiency is better for Morden and MSFH-17 under better conditions, where as under resource constraint conditions, KBSH-1 performed better in terms of partitioning efficiency. Moisture conservation and fertilizer application significantly influenced the oil content and yield.

Economics: Higher gross and net monetary returns were recorded with moisture conservation and fertilizer application over no moisture conservation and no fertilizer application.(Table 4) Deep soil recorded RS.8237/ha net returns resulting in Rs..5175/ha additional net income. The increase in net monetary returns with moisture conservation over no moisture conservation was to the extent of 31%. Fertiliser application recorded an additional net return of Rs.5460/ha over no fertilizer application. Variation in economic returns in Cultivars was also observed. Among the Cultivars, KBSH-1 recorded higher as well as net monetary returns fallowed by MSFH -17. The variation in returns from verities or Cultivars is mainly due to yields and the variation in price of the varieties. MSFH-I7 and APSH 11 recorded higher cost of cultivation, as the cost of the seed material was high. KBSH-1 recorded Rs. 19.70 higher benefit for the additional cost.

In conclusion it is suggested that for sustainable yields and better economic returns in rainfed Alfisols of semi arid regions, Recommended moisture conservation, fertilizer application and KBSH-1 Cultivars are the best options.

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ly in castor, *Ricinus communis* L.

..., G.N. Patel and H.C. Pathak

Main Castor-Mustard Research Station, Gujarat Agricultural University, Sardarkrushinagar-385 506, Gujarat

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Castor, *Ricinus communis* L. is grown under irrigated conditions in North Gujarat (AES-1) where the soils are sandy to loamy sand in texture and due to this leaching and volatilization losses of nitrogen are high. Earlier study showed that the castor responses to drip irrigation and economically higher yield was obtained with 0.8 ADFPE which saves 25% water and gives 36% higher yield over surface irrigation (Anonymous, 1996). Use of fertilizer has not been efficient due to higher costs and inefficient management. Therefore, most important approach to mitigate the fertilizer management problems would be to increase fertilizer use efficiency through adoption of 'fertigation' technique. With this view, an experiment was planned to workout economic fertilizer schedule through drip for castor.

A field experiment was conducted in randomized block design with six replications during rainy season of 1995-96 to 1997-98 at the Main Castor Mustard Research Station, Gujarat Agricultural University, Sardarkrushinagar with castor variety GCH-4. The soil is loamy sand in texture with pH 7.9, low in available nitrogen (142 kg/ha), medium in available P_2O_5 (55 kg/ha) and high in available K_2O (244 kg/ha). The crop was raised on 5th, 21st and 12th August during the year 1995, 1996 and 1997, respectively with adopting recommended package of practices with the inter and intra row spacing of 90 cm and 60 cm, respectively and basal fertilizer dose of 20-50-00 NPK kg/ha. The recommended dose for castor hybrid was 100-50 NP kg/ha. The treatments comprised four nitrogen levels *viz.*, 40, 60, 80 and 100 per cent of recommended N and nitrogen was applied in five splits through drip (fertigation). In surface flood, the recommended irrigation schedule, i.e., 6 cm depth of irrigation at 15-20 days interval and 100 per cent recommended nitrogen dose (100 kg/ha) were followed. The treatments under drip were irrigated at 0.8 pan evaporation fraction on alternate days, a recommendation for castor crop for this region (Anonymous, 1996).

The individual as well as pooled results of castor seed yield presented in table 1 showed that the seed yield differences due to different nitrogen levels were significant.

Table 1 Yield and economics as influenced by different N levels through fertigation in castor

Treatment	Seed yield (kg/ha)				Economics (Rs/ha)			
	1995	1996	1997	Pooled	Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	B:C ratio
40% N through drip	2435	2495	3466	2799	40585	9183	31402	4.42
60% N through drip	2659	2712	3677	3016	43732	9366	3436	5.09
80% N through drip	3013	3219	3825	3352	48604	9553	39051	5.44
100% N through drip	3239	3577	4160	3655	5297	9731	43266	4.31
100% N soil application (traditional method)	2592	2966	3749	3013	43688	10131	33557	
SEm±	153	112	148	78				
CD (P=0.05)	452	329	437	220				

Selling price of castor Rs. 1450/q and urea = Rs. 425/q

The significantly highest seed yield was recorded with the application of nitrogen @ 100 kg N/ha through drip and it was at par with 80 kg N/ha applied through drip during 1995 and 1997. The results corroborate the earlier findings in Gujarat in castor (Anonymous, 1999) and in cotton (Vaishnava *et al.*, 1995).

The results further indicated that application of 40 kg N/ha through drip gave comparable seed yield to that 100 kg N/ha by conventional (soil application) method. This may be due to better utilization of N owing to good development of root system of castor crop. Thus, through fertigation about 60% nitrogen fertilizer can be saved without any ill effect on castor seed yield. Fertigation, thus increased the fertilizer use efficiency as compared to normal fertilizer technique because decreased volatile and leaching losses.

The economical analysis showed that the maximum gross returns (Rs. 52997/ha), net returns (Rs. 43260/ha) and B:C ratio (5.44) obtained under 100% N through fertigation closely followed by 80% N through drip. Thus, these results showed that the farmers who have its own drip irrigation set, can apply 100 kg N/ha through drip (fertigation) for maximum yield, maximum net return and increased nitrogen use efficiency. Application of nitrogen through drip (fertigation) save 40 kg N/ha as compared to traditional method.

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Short communication

Intercropping of sunflower, *Helianthus annuus* L. with different legumes

Sanjeeb Kumar Sahoo, C. Radha Kumari, U. Obulamma and C. Raghava Reddy

Department of Agronomy, S.V. Agricultural College, Tirupati-517 502, AP

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Among different oilseed crops, sunflower is recently introduced in Andhra Pradesh and is grown over an area of 2.98 lakh ha. Earlier studies indicated that sunflower possesses enough flexibility in adjustments to an array of spacings. Sunflower is known for its yield adjustments to wide range of plant population from 0.5 to 1.5 lakh. Such plasticity helps to explore the possibility of intercropping with short duration pulses and oilseeds in its interspace and thereby effectively utilize the available resources. However, research efforts are still on to find out a suitable intercropping in sunflower. In the present investigation efforts have been taken up to find out suitable intercropping system of grain legume with sunflower and its effect on growth and yield of component crops in comparison with sole crop.

A field experiment was conducted during *rabi*, 1998-99 on sandy clay loam soil of Agricultural College Farm, Tirupati. The experiment consisted of 11 treatments which were laid in Randomized Block Design and replicated thrice (Table 1). In intercropping treatment 100% population was maintained for base crop of sunflower (60 x 20 cm) while, 50% population was maintained for intercrops by adjusting the intra row spacing with 7.5 cm for groundnut, greengram, blackgram and cowpea and 5 cm for soybean which were sown in between two sunflower rows. The soil of experimental field was neutral to slightly alkaline in reaction (pH 7.7) low in OC (0.22%) and available nitrogen (142 kg/ha), medium in available phosphorus (43 kg/ha) and available potassium (178 kg/ha). The sunflower variety, MSFH-17, groundnut variety, JL-24, greengram variety, ML 267, blackgram, LBG 20, cowpea variety, Pusa Phalguni and soybean variety, PK 471 were sown by applying fertilizer dose of 80:50:40 and 30:30:30 NPK kg/ha for sole crop sunflower and legumes, respectively. Half of N and entire P and K were applied basally by making a furrow with hand hoe at 5 cm away and at a depth of 5 cm adjacent to the respective seed row at the time of sowing in sunflower. For intercropping, entire N, P and K were applied as basal dressing as in sunflower. The sources of N, P and K were urea, SSP and MOP, respectively (Gross plot size : 5.4x4.8 m and net plot size : 4.4x3.6 m for sole crop and 4.6 x 2.4 m for intercropping).

Taller sunflower plants were produced with cowpea as intercrop. This might be due to fast growing nature of cowpea which offered greater spatial competition to sunflower during early stages which forced the plants to grow taller. Total DMP, LAI, total number of seeds and filled seeds/capitulum, 1000 seed weight, seed and stalk yield were maximum with sole crop of sunflower compared to intercropped treatments. Sonue and Chaskar (1991) and Sarkar and Dhara (1992) also reported reduced yield attributes and yield in intercropping. This might be due to acute competition due to higher plant density. Better growth of sunflower with higher LAI leading to better photosynthetic efficiency might be due to less competition offered by groundnut and blackgram to sunflower resulting higher yield attributes and yield in SF+GN and SF+BG intercropping system (Table 1). Seed yield of sole sunflower was significantly higher compared to all other treatments. Soundara Rajan and Srinivasulu Reddy (1991) and Sharma *et al.* (1995) were also of the same view. Among different intercropping treatments, SF + GN produced higher seed yield of sunflower which was on par with SF + BG but significantly superior to rest of the treatments. The reduction in above yield attributes, seed and stalk yield of sunflower was more when intercropped with cowpea.

Plant height of intercrops was higher compared to their respective sole crops. This might be due to shading offered by sunflower which forced the intercrops to grow taller for want of light. DMP, LAI, number of filled pods/plant, number of kernels or seeds/pod, test weight, seed or pod yield and haulm yield of all intercrops decreased in intercropping compared to their respective sole crops. Soundara Rajan and Srinivasulu Reddy (1991) and Shivaramu and Shivashankar (1992) were also of the same opinion. The reduction in the yield of intercrops might be due to reduced yield attributes as a result of more temporal and spatial competition offered by sunflower. Decrease in pod or seed yield of intercrops was relatively less in groundnut (52.2%) followed by balckgram compared to their sole crops. Per cent Light Interception (PLI) between sole crop rows was higher with groundnut, this might be due to groundnut growth was slower at early stages and only after 35 days the growth was vigorous (Table 1).

Table 1 Growth, yield attributes, yield and economics of sunflower and intercrops as influenced by different treatments

Treat-ment	Plant height (cm)		DMP (g/plant)		LAI		PLI		Total No. Seeds/ capitul um	No. Filled pods/ plant	No. Filled seeds/ capitul um	No. Of kernel or seeds/ pod	1000 seed weight (g)	100 pod weight (g)	Seed/pod yield (kg/ha)		Stalk yield (kg/ha)		B:C ratio
	S	I	S	I	S	I	BRS	BRSI	S	I	S	I	S	I	S	I	S	I	
T_1	140	-	95	-	1.9	-	48.6	-	1052	-	883	-	54.6	-	2757	-	3728	-	2.01
T_2	-	39	-	25	-	2.1	79.5	-	-	12.3	-	2.6	-	81.3	-	2469	-	4020	2.09
T_3	-	60	-	19	-	1.6	49.2	-	-	18.3	-	9.0	-	38.6	-	1564	-	1998	2.46
T_4	-	38	-	19	-	2.0	50.1	-	-	17.3	-	6.0	-	41.1	-	1303	-	1820	1.88
T_5	-	60	-	19	-	1.2	46.4	-	-	14.3	-	8.3	-	75.1	-	1453	-	2050	1.44
T_6		30	-	17	-	0.5	28.3	-	-	18.3	-	2.6	-	92.2	-	1385	-	1855	1.09
T_7	142	41	91	22	1.7	2.0	-	95.4	1047	9.8	865	1.9	52.4	79.7	2665	1180	3706	2056	2.47
T_8	145	65	89	15	1.6	1.5	-	90.1	1028	14.0	825	8.0	52.0	37.1	2496	680	3605	1040	2.00
T_9	143	40	90	15	1.7	1.8	-	92.3	1045	13.7	843	5.6	52.4	40.3	2654	610	3684	910	2.22
T_{10}	151	66	89	15	1.6	1.1	-	84.6	975	10.0	774	7.4	51.5	71.5	2327	624	3585	976	1.88
T_{11}	144	32	90	14	1.7	0.5	-	80.1	1036	14.0	834	2.4	52.3	89.5	2504	625	3652	909	1.88
SEm±	0.56	-	0.8	-	0.04	-	-	-	18.7	-	12.0	-	0.2	-	7.65	-	10.04	-	-
CD (P=0.05)	2.11	-	2.98	-	0.14	-	-	-	NS	-	44.8	-	0.9	-	23.03	-	30.26	-	-

T_1 : Sole SF (60 x 20 cm)
T_2 : Sole GN (22.5 x 10 cm)
T_3 : Sole GG (22.5 x 10 cm)
T_4 : Sole BG (22.5 x 10 cm)
T_5 : Sole CP (22.5 x 10 cm)
T_6 : Sole SB (30 x 5 cm)
T_7 : SF + GN
T_8 : SF + GG
T_9 : SF + BG
T_{10} : SF + CP
T_{11} : SF + SB
SF = Sunflower
GN = Groundnut
GG = Groundnut
GG = Greengram
BG = Blackgram
SB = Soybean
CP = Cowpea
S = Sunflower
I = Intercrops
PLI = Per cent light interception
BRS = Between rows of sole crop
BRSI = Between rows of sunflower and inter crop

Between rows of sunflower and intercrops, higher PLI was with SF + GN due to longer duration of groundnut and higher LAI. Net returns and B:C ratio were higher with SF + GN intercropping system followed by SF+BG intercropping system. This might be due to optimum yield of component crops in this system as a result of less competition. Venkata Krishna and Balasubramaniam (1997) also reported higher seed equivalents due to groundnut and blackgram, respectively because of their complementarity both in time and space.

It is evident that SF+GN in 1:1 row proportion at 100 and 50% population respectively would be more profitable followed by SF+BG intercropping system under irrigated conditions.

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Short communication

Studies on effect of herbicides in bunch groundnut, *Arachis hypogaea* L.

B. Sasikala, C. Radha Kumari, U. Obulamma and C. Raghava Reddy

Department of Agronomy, S.V. Agricultural College, Tirupati-517 502, AP

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Computational stress of weeds exert reduction in pod yield of groundnut to the extent of 17-84% (Guggari *et al.*, 1995). The pre-emergence herbicides like fluchloralin and pendimethalin were found to be effective in controlling the weeds after sometime. To overcome this situation, combination of pre and post-emergence herbicide application is necessary for better control of weeds. Several herbicides have been recommended to control annual grasses in groundnut (Kulandaivelu and Sankaran, 1986). Until recently, however, no soil applied herbicide was available to control most broad leaved weeds. Post-emergence application of imazethapyr provided effective control of numerous broad leaved weeds as well as nut sedge. As the research work done on the combination of post-emergence herbicides with pre-emergence herbicide was meagre, the present investigation was carried out to evaluate different herbicides combination on growth and yield of groundnut.

The field experiment was conducted at Agricultural College, ANGRAU at Wet Land Farm, Tirupati during *rabi*, 2000-01. The experimental field was sandy loam in texture, slightly alkaline in reaction (pH 7.8), low in O.C (0.21%), available nitrogen (130.6 kg/ha) and available phosphorus (20.5 kg/ha) and medium in available potassium (165 kg/ha). The experiment with 12 treatments was laid out in a Randomized Block Design with three replications (Table 1). Groundnut variety K 134 (Vemana) was grown as test crop with recommended dose of 20:40:50 NPK kg/ha by adopting 22.5 x 10 cm spacing, (gross plot size : 5 x 4.5 m and net plot size : 4.0 x 3.6 m). All the packages of practices except weed control were followed as per the recommendations.

Table 1 Growth, yield attributes, yield and economics of groundnut as influenced by different weed management practices

Treatment	Plant height (cm)	LAI	DMP (kg/ha)	No. nodules/ plant (at 40 DAS)	Nodule dry weight (at 40 DAS)	No. pegs/ plant	Total No. pods/ plant	No. filled pods/ plant	No. unfilled pods/ plant	100 pod weight (g)	100 kernel weight (g)	Shelling (%)	Pod yield (kg/ha)	Haulm yield (kg/ha)	HI (%)	B:C ratio
T_1	18	1.2	5055	84	3.1	11	9	4	5	70.1	31	65.3	846	1887	31.0	0.65
T_2	19	1.5	6094	91	3.2	14	10	6	4	72.4	34	68.1	1269	2313	35.4	1.29
T_3	24	1.6	7849	94	3.2	18	12	8	4	73.7	37	70.9	1644	2983	35.5	1.74
T_4	29	2.0	8619	127	5.2	19	14	12	2	78.7	40	72.9	2128	3851	35.6	2.37
T_5	24	1.6	7084	105	4.5	16	11	7	3	73.6	34	70.7	1420	2640	35.0	1.39
T_6	24	1.6	6987	108	4.5	16	11	8	3	73.9	34	70.7	1420	2648	34.9	1.28
T_7	23	1.6	6384	96	4.0	15	10	6	4	72.3	34	68.3	1274	2357	35.0	1.37
T_8	29	2.0	8641	120	5.1	20	15	12	2	79.3	39	72.0	2152	3781	36.3	2.51
T_9	29	2.1	8826	126	5.2	20	15	12	2	79.4	40	72.1	2162	3860	35.9	2.25
T_{10}	28	1.8	8245	102	4.7	18	13	10	3	75.6	37	71.5	1840	3512	34.4	1.87
T_{11}	28	1.8	8324	107	4.8	18	13	10	3	76.2	37	71.2	1850	3461	34.6	1.68
T_{12}	28	1.8	8192	101	4.6	19	13	10	3	76.6	37	71.6	1885	3471	35.2	2.23
SEm±	0.9	0.04	57.2	1.7	0.3	0.2	0.45	0.45	0.17	0.41	0.87	0.68	79.32	84.6	0.3	0.135
CD (P=0.05)	2.63	0.11	167.2	5.0	0.99	0.58	1.31	1.28	0.50	1.20	2.55	2.00	232	248	1.0	0.39

T_1 = No weeding (control)
T_2 = IC with star weeder at 20 DAS
T_3 = IC with star weeder at 20 DAS followed by HW at 40 DAS
T_4 = HW at 20 and 40 DAS
T_5 = PPI of Fluchloralin @ 1.5 kg a.i./ha
T_6 = PE application of pendimethalin @ 1.5 kg a.i./ha
T_7 = Post-emergence application of Imazethapyr @ 75 gm a.i./ha
T_8 = Fluchloralin @ 1.5 kg a.i./ha as PPI fb Imazethapyr @ 75 gm a.i./ha at 20 DAS
T_9 = Pendimethalin @ 1.5 kg a.i./ha as PE fb Imazethapyr @ 75 gm a.i./ha at 20 DAS
T_{10} = Fluchloralin @ 1.5 kg a.i./ha PPI fb HW at 40 DAS
T_{11} = Pendimethalin @ 1.5 kg a.i./ha as PE fb HW at 40 DAS
T_{12} = Imazethapyr @ 75 gm a.i./ha at 20 DAS fb HW at 40 DAS

IC = Intercultivation; fb = followed by; HW = Hand weeding; PPI = Pre-Plant Incorporation; PE = Pre-Emergence

Plant height, LAI, DMP and number as well as dry weight of nodules were higher with pendimethalin followed by imazethapyr which was on par with fluchloralin followed by imazethapyr and hand weeding twice (20 and 40 DAS). This was due to lesser weed density and biomass in these treatments, resulting in reduced competition between crop and weed for growth factors (Table 1). Similar results were observed by Murthy *et al.* (1992).

The number of pegs/plant, total number of pods/plant, filled pods/plant, 100 pod weight, 100 kernel weight, shelling percentage were more with pre-emergence application of pendimethalin followed by imazethapyr at 20 DAS and was comparable with fluchloralin followed by imazethapyr and hand weeding twice (20 and 40 DAS) (Table 1). This was due to maintenance of weed free environment during critical stages of crop growth, which would have resulted in better availability of nutrients and moisture to the crop. This was evidenced from the better stature of crop, as reflected by increase in LAI and DMP of crop. These results are in agreement with the findings of Rafey and Prasad (1995).

Highest pod and haulm yield and harvest index (HI) was obtained from the application of pendimethalin followed by imazethapyr or hand weeding twice at 20 and 40 DAS (Table 1). This might be due to maintenance of weed free environment, especially during critical stages of crop growth, as evident from increased in plant height, LAI and DMP. Improvement in growth parameters obviously increased the yield attributes like number of filled pods/plant, 100 pod weight, 100 kernel weight and shelling percentage and ultimately the pod yield. Severe weed competition for growth resources under unweeded control affected the growth and yield attributes leading to poor pod yield. These results are in agreement with those reported by Battacharya *et al.* (1996).

The highest net returns and B:C ratio were realized with the application of fluchloralin followed by imazethapyr which was followed by hand weeding twice or pendimethalin followed by imazethapyr, this was due to lesser unit cost of fluchloralin and higher pod yield in these treatments. These results are in agreement with earlier findings of Maliwal and Rathore (1994).

Therefore, pre-plant incorporation of fluchloralin (as its unit cost is less) at 1.5 kg a.i./ha followed by imazethapyr at 75 g a.i./ha at 20 DAS and pendimethalin followed by imazathapyr provided effective weed management and gave equally higher yield of irrigated groundnut.

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Short communication

Bioefficacy of haloxyfop ethyl for weed control in soybean, *Glycine max* (L.) Merrill

S.D. Billore, A.K. Vyas and O.P. Joshi

National Research Centre for Soybean, Indore-452 017, MP

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Soybean has flourished as one of the major *kharif* crops of the central India. Being a rainy season crop, infestation with weeds contributes significantly in limiting yield expression of the crop. Billore *et al.* (1999) reported that these losses could be as high as 69%. The monocot weeds have greater competitive stress on growth and yield of soybean than broad leaf weeds. At present, herbicides largely in use for managing weeds are suitable for pre-plant or pre-emergence applications. Only couple of post-emergence herbicides are under recommendation. However, the recommendation of post-emergence herbicides for selective suppression of monocot weeds in soybean is lacking. In view to provide option to farmers, a new herbicide molecule i.e., haloxyfop ethyl (10EC) was evaluated for its bio-efficacy for controlling the weeds in soybean.

The experiment was carried under Randomised Block Design and replicated thrice during *kharif*, 2001 at National Research Centre for Soybean, Indore, Madhya Pradesh. The soil of experimental site belonged to fine, montmorrillonitic, isothermic family of Typic Chrumosterts. It analyzed: pH 7.8, EC 0.14ds/m, organic carbon 0.3%, available phosphorus 10.1 kg/ha and available potassium 280 kg/ha. Haloxyfop and imazethapyr was applied as post emergence at 15-21 days after sowing. Soybean cv. JS 335 was raised following the recommended package of practices.

The observations on yield and yield attributes were recorded at harvest. Weed population species wise and their oven-dry weight was recorded at 30 and 60 days after sowing. The weed control efficiency (WCE) was computed by using the formula, WCE = x-y/y.100; where x and y, respectively, refer to dry weight of weeds at specific sampling in weedy check and particular treatment for which the value is computed. Weed index was also computed as per standard formula. Necessary statistical analyses were carried out by method of Sokal and Rohlf, (1981).

In general, the treatments evaluated for weed control in the study yielded numerically higher (6 to 31%) than weedy check (Table 1). The maximum seed yield was recorded with the treatment two hand weeding (2479 kg/ha) and remained at par with imazethapyr @ 100 g/ha (2238 kg/ha). However, the yield differences between imazethapyr, haloxyfop ethyl @ 100 g/ha (2138 kg/ha) and alachlor @ 2 kg/ha (2119 kg/ha) were also non-significant. The total yield loss estimated due to weed competition was the 38.91% as compared to two hand weeding.

Table 1 Effect of haloxyfop ethyl on weed flora and performance of soybean

Treatment	Dose (kg a.i./ha)	Mode of application	Monocot weeds at 30 DAS		Monocot weeds at 45 DAS		Dicot weeds at 30 DAS		Dicot weeds at 45 DAS		Total weeds at 30 DAS		Total weeds at 30 DAS		Yield (kg/ha)
			Dry weight (g/m^2)	WCE*	Dry weight (g/m^2)	WCE*	Dry weight (g/m^2)	WCE*	Dry weight (g/m^2)	WCE*	Dry weight (g/m^2)	WCE*	Dry weight (g/m^2)	WCE*	
Haloxyfop ethyl	0.050	POE**	3.0	95.8	0.0	100.0	48.9	-	84.6	-	51.9	52.6	84.6	37.8	1924
Haloxyfop ethyl	0.075	POE	0.0	100.0	0.0	100.0	57.7	-	87.2	-	57.7	47.3	87.2	35.8	1975
Haloxyfop ethyl	0.100	POE	0.0	100.0	0.0	100.0	61.8	-	104.4	-	61.8	43.7	104.4	23.2	2138
Haloxyfop ethyl	0.125	POE	0.0	100.0	0.0	100.0	66.0	-	103.0	-	66.0	39.8	103.9	23.6	1894
Imazethapyr	0.100	POE	3.2	95.6	0.0	100.0	17.0	53.8	0.0	100.0	20.2	81.5	0.0	100.0	2238
Alachlor	2.000	PE***	1.8	97.6	12.5	77.35	27.2	26.4	62.6	22.5	28.9	73.6	74.5	45.2	2119
Two hand weeding at 3rd and 6th weeks after sowing			0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	2479
Weedy check			72.7	-	55.2	-	36.9	-	80.7	-	109.6	100.0	135.9	-	1785
SEm±			16.52	-	19.40	-	13.00	-	20.56	-	17.82	-	25.32	-	81
CD (P=0.05)			50.10	-	58.80	-	39.43	-	62.37	-	51.05	-	76.81	-	244

* Weed control efficiency, ** Post-emergence, *** Pre-emergence

The predominant weed flora encountered during the season was *Echinocloa crusgalli*, *Digitaria* spp., *Dinebra arabica*, *Cyperus rotundus*, *Euphorbia geniculata*, *Digera arvensis* and *Commelina benghalensis*.

All the treatments of haloxyfop ethyl and two hand weeding almost eliminated the monocot weeds at 30 DAS as well as 45 DAS as indicated by weed control efficiency of 95% and above. The tested herbicide had an edge over imazethapyr and alachlor in monocot weed control. The application of *haloxyfop ethyl at variable concentrations was not effective* in controlling dicot weeds at any stage of crop growth. Imazethapyr and alachlor were effective in control of dicot weeds. The effectivity of farmer herbicide increased with time whereas it decreased in case of later. Comparison of the total weed scenario revealed that the weed control efficiency of two hand weeding, imazethapyr and alachlor was superior over haloxyfop ethyl at both the stages of observations.

The results suggest that the haloxyfop ethyl is viable option to manage weeds in fields with dominance of monocot flora or to diversity use of herbicides alternatively from year to year. On the contrary imazethapyr and alachlor are better options in fields with mixed/dicot flora.

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Short communication

Influence of different sowing dates on insect-pest incidence and yield losses in *kharif* groundnut, *Arachis hypogaea* L.

A.K. Awasthi, R.K. Shukla and S.R. Patel

Indira Gandhi Agricultural University, Krishi Vigyan Kendra, Sarkanda Farm, Bilaspur-495 001, CG

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Groundnut (*Arachis hypogaea* L.) is one of the important oilseed crop grown under rainfed condition during *kharif* and under irrigated condition during *rabi*-summer season in Chhattisgarh state. The average productivity of *kharif* groundnut is very low (963 kg/ha) as compared to national average. Many factors are responsible for low productivity, insect-pest damage is major one of them. Though more than 120 species of insects are known to feed on groundnut and about a dozen of them are economically important in India (Wightman and Amin, 1988). The estimated yield losses due to pest complex of groundnut has been reported to vary from 21.93 to 83.2% (Singh and Rawat, 1981; Sivasubramanian and Palanisamy, 1986; Brar *et al.*, 1995). It is an established fact that sowing time of season bound crop has profound effect on the incidence of pests as most of the insect pests infest the plant at particular crop growth stage and under certain environmental conditions. Numbers of workers have studied the influence of sowing dates on insect-pest incidence and yield losses in groundnut crop (Lewin *et al.*, 1979; Dash and Santokke, 1994; Shetgar *et al.*, 1994) in different parts of the country. The information pertaining to incidence of insect-pest and yield loss in Chhattisgarh is very meager. Therefore, the present study was undertaken to find out the influence of different sowing dates on the incidence of insect-pests and to assess the yield losses in groundnut, which would help to evolve a suitable insect-pest management strategy.

The field experiments were conducted at the Regional Agricultural Research Station, IGKV, Bilaspur during *kharif*, 1998-99 to study the influence of different sowing dates on the insect-pest incidence and yield losses. Groundnut variety 'J-11' was sown at 14-day intervals starting from 18th June to 30th July during both the years. The treatments consisting of four sowing dates and two-crop condition i.e., protected and unprotected were laid out in Split Plot Design with four replications. The seeds were sown in furrows keeping 30 cm row to row and 10 cm plant-to-plant spacing. All the agronomic practices were followed as per the local recommendations excepting that no insecticide was applied in unprotected crop. In protected plots need based application of recommended insecticide monocrotophos was made.

The observations were recorded on number of leaf hopper/3 leaves, leaf mines formed due to leaf miner and per cent leaf-let damage due to leaf eating caterpillars was assessed on the basis of damaged and total leaves/plant on 5 randomly selected plants/plot at weekly interval in the plots under unprotected condition. Observations on yield were recorded at the time of harvest in both protected and unprotected plots under different dates of sowing. The data on pest incidence and grain yield were subjected to statistical analysis. Correlation and regression equations were also worked out to assess the influence of individual insects on yield.

Leaf hopper (*Empoasca kerri* Pruthi), leaf miner (*Aproaerema modicella* Deventer) and leaf eating caterpillars (*Spodoptera litura* Fab., *Anarsia ephippias* Meyrick, *Spilosoma obliqua* Walk., *Amsacta albistriga* Walk) were recorded to be the major insect pests of groundnut during *kharif* season in both the years.

Insect-pest incidence: Significant difference in insect pest incidence was noticed with respect to different sowing dates (Table 1). In general, the crop sown on June 18 and July 02 had recorded minimum incidence of most of the insect-pests. The population of leafhopper (1.76/3 leaves) was the maximum on the crop sown on July 30. It was observed significantly low (0.99-1.07/3 leaves) on the crop sown on June 18 and July 02. Leaf miner and leaf eating caterpillars inflicted maximum damage of 3.13 mines/plant and 40% leaf-let/plant, respectively to the crop sown on July 16. However, rest of the sowings recorded comparatively lower damage due to these pests. Dash and Santokke (1994) also reported that the crop sown in third week of June and first week of July had minimum incidence of foliage feeding insects as compared to the crop sown in third week of July. Although, Shetgar *et al.* (1994) observed maximum population of leafhoppers (1.33/3 leaves) and leaf miner (1.11/plant) on June 15 and July 15 sowings, respectively.

Yield and yield losses: The data presented in Table 2 revealed that there was significant variation in pod yield due to different sowing dates during both the years. Sowing of groundnut up to July 02 produced higher pod yield as compared to delayed sowing in both the conditions. On the

mean basis highest pod yield of 1426 kg/ha was obtained under protected condition from the crop sown on June 18 and there was a decreasing trend with lowest yield of 855 kg/ha in the crop sown on July 30. Similar trend with respect to yield was obtained under unprotected condition in which the highest pods yield of 1133 kg/ha and lowest yield of 637 kg/ha was recorded in the crop sown on June 18 and July 30, respectively. Nevertheless, crop sown on July 30 recorded comparatively lower damage due to leaf miner and foliage eating caterpillars; less yield might be due to agronomical impact of sowing date on the yield. Shetgar *et al.* (1994) also recorded highest pod yield with the crop sown on June 15 followed by July 01 sowing. While, pod yield has been recorded highest in the crop sown during first week of July followed by sowing on June third week (Shantimalliah *et al.*, 1979; Dash and Santokke, 1994).

The pooled data for two years showed that the protected crop recorded significantly higher average yield (1125 kg/ha) than the unprotected crop (859 kg/ha) under different sowing dates which clearly indicates the impact of plant protection against insect-pest complex of groundnut. Brar *et al.* (1995) also observed significantly low population of foliage feeding insects along with higher yield in the treated plots as compared to untreated crop. Panchbhai and Raj (1987) also reported that plots protected from *S. litura* by monocrotophos gave the maximum yield of groundnut.

The average pod yield losses in the crop sown on June 18, July 02, July 16 and July 30 were to the tune of 20.6, 23.2, 27.2 and 24.5%, respectively (Table 2). Shetgar *et al.* (1994) observed the yield loss in the range of 23.9-31.7% under four dates of sowing starting from June 15 to July 30 at an interval of 15-day.

Relationship between yield v/s insect-pest incidence: Correlation and regression analysis was performed and the linear model Y= a+bx was used to describe the functional relationship between yield of groundnut and insect pests incidence at different dates and over to dates of sowing. Where Y = predicted mean yield of groundnut; a = intercept; b = regression coefficient and x represents leafhopper/3 leaves (IP1), leaf mines/plant (IP2) and per cent leaf let damage (IP3), respectively.

The data showed significant and positive correlation (r=0.906) between first date of sowing and leafhopper/3 leaves (IP1). The yield of groundnut may be predicted by the given equation (Y=-1274.1 + 1977 X). Similarly, the correlation and prediction equation among respective variables are given in Table 3 by which the yield of groundnut can be predicted in different dates of sowing for various insect-pest incidence.

Correlation analysis between yield of groundnut and insect-pests incidence, leafhopper/3 leaves (IP1) and per cent leaf let damage (IP3) showed significant and negative correlation, while leaf mines/plant (IP2) revealed non-significant correlation over different dates of sowing.

Table 1 Influence of sowing time on the incidence of different insect-pests in *kharif* groundnut

Sowing dates	*Insect-pests incidence*								
	Average Leafhopper/3 leaves (No.)			Average Leaf mines/plant (No.)			Average Leaf let damage (%)		
	1998	1999	Mean	1998	1999	Mean	1998	1999	Mean
18th June	1.20 (1.30)	0.78 (1.13)	0.99 (1.22)	2.78 (0.90)	2.23 (1.64)	2.50 (1.72)	29.71	31.8	30.8
2nd July	1.21 (1.31)	0.94 (1.19)	1.07 (1.25)	3.01 (1.88)	2.12 (1.62)	2.56 (1.75)	34.43	35.7	35.1
16th July	1.62 (1.46)	1.48 (1.40)	1.55 (1.43)	3.15 (1.90)	3.12 (1.90)	3.13 (0.73)	38.72	41.4	40.1
30th July	1.67 (1.47)	1.85 (1.52)	1.76 (1.50)	2.44 (1.71)	2.65 (1.77)	2.54 (1.74)	35.44	38.1	36.8
CD (P=0.05)	0.07	0.24	0.08	NS	0.17	0.09	NS	NS	5.45
CV (%)	5.97	11.34	8.10	-	6.34	6.90	-	-	13.52

Figures in parenthesis are $\sqrt{(x+0.5)}$ transformed values

Table 2 Yield losses in groundnut due to various insect-pests under different dates of sowing

Sowing dates	Pod yield (kg/ha)									Avoidable yield losses (%)		
	1998			1999			Pooled					
	Pr.	UnPr.	Mean	Pr.	UnPr.	Mean	Pr.	UnPr.	Mean	1998	1999	Mean
18th July	1632	1340	1486	1221	926	1073	1426	1133	1280	17.9	24.2	20.6
2nd July	1563	1261	1412	922	647	784	1243	954	1098	19.3	29.9	23.2
16th July	1281	986	1133	671	436	553	976	711	843	23.0	35.1	27.2
30th July	1076	846	961	635	429	532	855	637	746	21.4	32.4	24.5
CD (P=0.05)												
Sowing dates	:	89.31			86.65			57.79				
Plant Protection	:	107.88			60.96			82.99				
CV (%)	:	11.22			10.57			11.47				

Pr. = Protected crop condition; UnPr. = Unprotected crop condition

Table 3 Correlation and regression analysis between groundnut yield and insect-pests incidence at different dates of sowing

Sowing dates	Leafhopper/3 leaves (IP1)	Leafmines/plant (No.) (IP2)	Leaf let damage (%) (IP3)
18th June	(0.906)* Y=-1274.1+1977 X	(-0.075) Y = 1214.8-47.6 X	(-0.524) Y=1558.8-13.8 X
2nd July	(0.238) Y=1196.6+1727.9X	(0.489) Y=-1017.7+1158.5X	(0.741)* Y=2431-40.5X
16th July	(-0.262) Y=1583-609.6X	(0.606)* Y=1718.9-530.4X	(0.029) Y=735.3-0.62X
30th July	(-0.877)* Y=1449.6-542.4X	(0.827)* Y=-932.8+901.7X	(0.652)* Y=1160.8-14.2X

* Significant at 5%.

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Short communication

Incidence of cabbage butterfly, *Pieris brassicae* (L.) on different *Brassica* species

A. Kamboj, J.S. Rana and Ombir

Department of Entomology, CCS Haryana Agricultural University, Hisar-125 004, Hisar

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Cabbage butterfly, *Pieris brassicae* (L.) is a pest with wide host range infesting several species of food plants belonging to Cruciferae, Tropaeolaceae, Capparaceae, Resedaceae and Papilionaceae (Feltwell, 1982). It has been found feeding on cabbage, cauliflower, *Karan sag, raya, sarson, taramira*, turnip and radish (Rataul, 1959). The incidence of this pest is serious on rapeseed and mustard plants during some years (Anonymous, 1994). The studies on the pattern of incidence of this pest in *Brassica* species were thus undertaken to record its pattern of incidence in agro-climatic conditions of Haryana.

Nine *Brassica* species were observed for the relative incidence of *P. brassicae* under field conditions at CCSHAU, Hisar during *rabi*, 2001-02. The experiment was laid out under Randomized Block Design in a plot size of 7.2 m^2 per *Brassica* species and replicated three times (Table 1). All the recommended agronomic practices (Anonymous, 2000) except the application of pesticides were followed to raise the crop.

The observations on pest infestation index (Bhalla *et al.*, 1996) were recorded weekly starting 20 days after sowing till harvest of the crop on 10 randomly selected plants per species. The early maturing *Brassica* species *viz., Brassica campestris* var. (BSH-1 and YSPB-24), escaped the pest infestation. The incidence was observed only on late maturing *B. napus* (var. HNS-9605), *B. nigra* and *B. carinata* (var. HC-9605) species. Incidence on *B. napus* (var. HNS-9605) ranged from a 6.71 to 23.3 per cent during 7th, 8th and 9th standard week. Incidence on *B. nigra* started from 7th standard week and infestation was maximum (13.3%) during standard week 10. Incidence on *B. carinata* (var. HC-9605) started from 6th week with 3.3 per cent plant infestation and was recorded upto 11th standard week. Plant infestation of *B. carinata* (var. HC-9605) was maximum (36.67%) during 8th and 9th standard week.

The incidence of this pest on cabbage, cauliflower and other crucifers has been reported by earlier workers like Sachan and Gangwar (1980; 1990) reported this pest throughout the year on cole crops in Meghalaya with maximum activity during February to October. Gupta (1984) observed larval incidence of *P. brassicae* high upto May in mid-hills of Himachal Pradesh. Sood and Bhalla (1996) reported the incidence of *P. brassicae* in February-March at Nauni (Himachal Pradesh) with peak activity in third week of April and incidence was 40 and 50% on cabbage and cauliflower, respectively, which support the result in present studies.

Average number of larvae/plant varied from 0.63 to 2.97 on *B. napus* (var. HNS-9605), 0.57 to 1.73 on *B. nigra* and 0.40 to 6.70 on *B. carinata* (var. HC-9605). The highest larval population was observed during 7th week on *B. napus* (var. HNS-9605) and *B. nigra* while during 8th week on *B. carinata* (var. HC-9605).

Earlier studies on the aspect revealed that number of larvae per plant was higher initially which decreased later due to gregarious feeding habit of this pest during first three larval instars with late instars spreading on different plants (Bhatia and Verma, 1995). Likewise, Sachan and Gangwar (1990) recorded 6-120 larvae/plant during peak period of incidence. However, Bhatia and Verma (1994) observed 222.5 larvae/plant. Prasad and Lal (2000) recorded 5-15 full grown caterpillar/plant were recorded on *B. carinata*.

Pest infestation index varied from 0.04 to 0.69 on *Brassica napus* (var. HNS-9605), 0.08 to 0.23 on *B. nigra* and 0.04 to 2.46 on *B. carinata* (var. HC-9605). The infestation index was maximum during 7th standard week on *B. napus* (var. HNS-9605) and *B. nigra* while it was mainly in *B. carinata* during 8th standard week.

Sood and Bhalla (1996) reported peak infestation index (11.7) of this pest during third week of April on cabbage and 18.9 on cauliflower. Likewise, Bhalla *et al.* (1997) recorded a minimum pest index of 1.25 on Pusa Jai Kisan amongst 12 *B. juncea* cultivars screened with a maximum infestation index (4.50) on EC-333568. They further reported infestation index as 2.13 on *B. napus* cultivar BEC 335, 3.30 on *B. nigra* cultivar EC-289660 and 2.64 and 3.60 on *B. carinata* cultivars EC 223405 and EC-151995A, respectively. The varying infestation indexes across different cultivars of *Brassica* are similar to those recorded in the present studies.

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Table 1 Incidence of *Pieris brassicae* (L.) under field condition

Species	Standard week						Mean
	6th	7th	8th	9th	10th	11th	
Larval population/plant							
B. napus (var. HNS-9605)	0.63±0.55	2.97±1.15	2.50±1.01	2.07±0.91	0.90±0.40	0	1.81
B. nigra	0	1.73±0.42	1.30±0.26	0.97±0.21	0.57±0.21	0	1.14
B. carinata (var. HC-9605)	0.40±0.29	6.10±2.27	6.70±1.61	5.47±1.37	2.73±0.84	0.53±0.25	3.65
Incidence (%)							
B. napus (var. HNS-9605)	6.67±5.77 (14.82*)	23.33±5.77 (29.45)	23.33±5.77 (29.45)	23.33±5.77 (29.45)	16.67±5.77 (24.63)	0 (5.74)	(22.26)
B. nigra	0 (5.74)	13.33±5.77 (21.99)	13.33±5.77 (21.99)	13.33±5.77 (21.99)	13.33±5.77 (21.99)	0 (5.74)	(16.58)
B. carinata (var. HC-9605)	3.33±2.77 (10.28)	26.67±11.55 (31.44)	36.67±5.77 (37.81)	36.67±5.77 (37.81)	23.33±5.77 (29.45)	6.67±4.55 (12.91)	(26.62)

	Incidence CD (P=0.05)	SEm±		Larval population CD P=0.05)	SEm±
Factor			Variety (A)	0.35	0.13
Variety (A)	1.99	0.71	Observation period (B)	0.28	0.11
Observation period (B)	1.63	0.58	A x B	0.86	0.31
A x B	4.87	1.74			

Figures in parenthesis are angular transformed values

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Short communication

Evaluation of soybean [*Glycine max* (L.) Merrill] genotypes for insect resistance/tolerance against major insect pests

Amar N. Sharma, Ashish Garewal and R.N. Singh

National Research Centre for Soybean, Khandwa Road, Indore-452 017, MP

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Although, some insect resistant/tolerant sources like TG x 855-53D, L-129, DS-396 etc., have been identified (Sharma, 1996) and are being used in hybridization programmes, but still in view of new genetic material being developed every year, the process has to be continued. Present study was, therefore, undertaken to evaluate some varieties and selections from germplasm lines, for resistance against specific major insect pests as well as against prevailing insect pest complex *per se*. An experiment was laid out in Randomized Block Design with three replications and 45 cms row-to-row distance at National Research Centre for Soybean, Indore during 2000-01. Ten genotypes differing in maturity, were sown in two sets - one completely insect protected with the help of insecticides and other unprotected (Table 1). Observations on different major insect pests of soybean were recorded and analysis was done as per the conventional procedure of AICRP's method and by 'maximin-minmax' procedure (Odulaja and Nokoe, 1993). Genotypic variation in soybean genotypes with respect to different insect pests and yield are presented and discussed below:

Defoliators: On the basis of defoliators' population (green semiloopers and tobacco caterpillar) variety JS 71-05 was identified as highly resistant and NRC 25 (selection from germplasm line EC 109545) as resistant to green semiloopers. Similarly, variety JS 71-05 and NRC-33 (selection from germplasm line EC 251372) were found to be highly resistant while NRC-18 (selection from germplasm line EC 39739) and NRC 7 as resistant to tobacco caterpillar (Table 1). However, extent of leaf area damage (which actually results in yield losses) did not essentially commensurate with the population of defoliators. Variety JS 71-05, which was found to be highly resistant to defoliators on the basis of insect population, was found to have low level of resistance (LR) with 42.46% leaf area damaged. Likewise, variety JS 80-21, which showed susceptibility to defoliators on the basis of insect population, had least leaf area damage of 18.63% and thus rated as highly resistant. It clearly indicated that leaf area damage was more appropriate criterion for assessing the genotypes for resistance against defoliators (Sharma, 1995; 1996).

Table 1 Categorization of soybean genotypes for resistance against defoliators on the basis of insect population/damage

Genotype	Population of defoliators (per m row)				Leaf area damage (%)	
	Green semilooper		Tobacco caterpillar			
NRC 18	7.2 (2.7)*	LR	0.8 (0.9)*	R	47.6 (43.6)#	LR
NRC 25	4.8 (2.2)	R	1.0 (2.0)	MR	48.1 (43.9)	LR
NRC 33	8.0 (2.7)	LR	0.6 (0.7)	HR	40.1 (39.2)	LR
JS 335	6.2 (2.6)	LR	1.9 (1.3)	LR	54.0 (47.5)	HS
L 129	6.7 (2.6)	LR	2.2 (1.5)	S	32.4 (34.6)	MR
JS 71-05	2.8 (1.7)	HR	0.4 (0.7)	HR	42.5 (40.7)	LR
NRC 7	7.0 (2.6)	LR	0.8 (0.9)	R	22.4 (27.7)	R
Bragg	6.0 (2.4)	MR	0.9 (0.9)	MR	27.2 (31.4)	MR
JS 80-21	8.8 (2.9)	S	4.0 (2.0)	HS	18.7 (25.2)	HR
MACS 450	9.3 (3.0)	S	3.4 (1.8)	HS	38.9 (35.9)	MR
Mean	6.7 (1.2)		1.6 (1.2)		36.8 (36.9)	
F-test	Significant		Significant		Significant	
SEm±	0.12		0.1		2.4	
CD (P=0.05)	0.4		0.3	7.1		

* Square root transformed values are given in parentheses.
\# Angular transformed values are given in parentheses

Girdle beetle: None of the entries was found to be resistant against girdle beetle (*Obereopsis brevis*) on the basis of both, per cent infestation as well as per cent plant damage. However, the least per cent plant damage was observed in L 129 (61.11%) and maximum in case of NRC 18, NRC 33, NRC 7, JS 71-05 and JS 335 (83.33%) was observed during present study, confirming earlier findings of Sharma (1995).

Jassids: Categorization of genotypes for resistance against jassids was done on the basis of population at 60 DAG. Accordingly, only NRC 18 was rated as highly resistant with 1.44 jassids/m.

Stem fly: Varieties JS 335, JS 80-21 and Bragg were found to be highly resistant to stem fly on the basis of stem tunneling (Table 2). However, Talekar and Chen (1986) maintained that seedling mortality due to stem fly attack should be considered for evaluating soybean genotypes for resistance studies. In the present study, although the differences in seedling mortality were non-significant, NRC 7 was categorized as highly resistant to stem fly infestation.

Table 2 Categorization of soybean genotypes for resistance against stem fly on the basis of damage and by maximin-minimax method

Genotype	Stem fly				Grain yield (kg/ha)		Yield loss (%)	Relative yield (RY)	Relative % yield loss (RP)	Category
	% seeding mortality		% Stem tunneling		UP	P				
NRC 18	10.0 (18.1)#	LR	52.5 (46.5)#	HS	686	694	1.2	66.5	2.3	R-LY
NRC 25	8.0 (16.0)	MR	46.6 (43.1)	S	619	793	21.9	66.0	44.4	S-LY
NRC 33	11.0 (18.8)	LR	33.1 (33.9)	MR	854	1198	28.7	82.8	58.1	S-HY (T)
JS 335	8.7 (16.6)	MR	25.3 (30.2)	HR	796	1540	48.3	77.2	97.8	S-HY (T)
L 129	10.8 (18.9)	LR	57.1 (49.4)	HS	1031	1298	20.6	100.0	41.7	S-HY (T)
JS 71-05	10.7 (18.5)	LR	38.5 (38.2)	LR	530	1047	49.4	51.4	100.0	S-LY
NRC 7	5.1 (12.9)	HR	34.2 (35.7)	MR	625	933	33.0	60.6	66.9	S-LY
Bragg	6.8 (15.0)	MR	27.1 (31.4)	HR	619	1016	39.1	60.0	79.1	S-LY
JS 80-21	11.8 (19.6)	LR	24.2 (29.5)	HR	716	1213	41.0	69.5	83.0	S-LY
MACS 450	7.9 (16.0)	MR	24.3 (40.5)	LR	884	1018	13.2	84.7	26.7	S-HY (T)
Mean	9.1 (17.1)		37.9 (37.8)							
F-test	NS		Significant							
SEm±	-		1.6							
CD (P=0.05)	-		4.7							

* *Square root transformed values are given in parentheses, # Angular transformed values are given in parentheses*
UP = Un-Protected; P = Protected; R = Resistant; S = Susceptible; T = Tolerant; HY = High Yielding; LY = Low Yielding

Yield: The *kharif*, 2000 season was a weak rainy season for Madhya Pradesh, as it received only about 50% (497 mm) of average annual rainfall, and caused considerable yield reduction. However, based on the yields obtained under insect protected and unprotected conditions, it was found that per cent yield loss in different genotypes ranged from 1.15 in NRC 18 to 49.38% in JS 71-05 (Table 2). Genotype L 129 with the highest yield under unprotected condition (1031 kg/ha), was considered as resistant check, while JS 71-05 with the maximum per cent yield loss (49.38%) was considered as susceptible check. In relation to these checks, relative yield (RY) and per cent yield loss (RP) were calculated. Accordingly, genotype NRC 18 was categorized under resistant but low yielding (R-LY). It was serve as a donor for insect resistant character against the pest complex in developing resistant varieties. On the other hand, genotypes NRC 33, JS 335, L 129 and MACS 450 were grouped under susceptible but high yielding (S-HY) i.e., tolerant.

The results of two screening methods clearly emphasize the importance of appropriate screening method that should be adopted keeping in view the specific purpose of screening.

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Short communication

Screening of sesame genotypes against stem and root rot, *Macrophomina phaseolina*

T.S. Rajpurohit, Z.S. Solanki and D.B. Ahuja

Agricultural Research Station, Rajasthan Agricultural University, Mandor, Jodhpur-342 304, Rajasthan

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Macrophomina stem and root rot of sesame (*Sesamum indicum* L.) caused by *Macrophomina phaseolina* (Maubl.), Ashby is an important disease of sesame in Rajasthan. It causes high mortality of plants and consequently results great losses in seed yield under rain fed condition of western Rajasthan. Varietal resistance offers ecofriendly mean of managing the disease. Mirza *et al.*, 1986 and Rajpurohit 1997 reported sesame resistance lines against this disease. However information on screening of varieties for resistance under sick plots condition is not available. With this view, 25 sesame genotypes were screened under disease sick plot at Agricultural Research Station Mandor, Jodhpur during *kharif*, 2000 to 2001 to find out resistant sources.

A disease sick plot of 25x30 m was developed at the research station as described by Nene *et. al.* (1981).Test sesame genotypes were sown in sick plot in July 2000 and 2001 after the onset of monsoon.. Each entry was sown with 30 cm distance in 4 m row length in Randomized Block Design replicated twice with susceptible variety VRI-1 planted after each test entry as check. The observations on initial plant stand were recorded, 7 days after sowing. Percent Disease incidence was recorded at 30, 45,and 60 days after sowing (Table 1) on 0 to 5 point disease scale:.

<1	immune
1-10%	Resistant
11-20 %	Moderately resistant
21-50%	Moderately susceptible
51-70%	Susceptible
70-100%	Highly susceptible

Out of 25 genotypes screened, 7 genotypes *viz*; EC-370932, EC-351832, EC 370929, ES-379-3-84, IS-646-1, IS-97, IS-100B were estimated as resistant, 9 genotypes *viz*; EC-351819, EC-370823, EC-370663, ES-29, ES-115-2-84, ES-123-2-84, ES-135, ES-319-2-84, ES-99 showed moderate resistance, 7 genotypes *viz*; EC-370773, EC-370867, ES-139-2-84, ES-1-2-84, Dhanera-1, RT-103, RT-46 were moderately susceptible and two genotypes VRI-1 and TC-25 were susceptible consequently for two years. Identified sources can be utilized in the hybridization programme to develop resistant varieties of sesame.

Table 1 Screening of sesame genotypes against Macrophomina stem and root rot

Genotype	*Disease intensity (%)		
	2000	2001	Mean
EC-351819	14.0 (21.94)	16.9 (24.27)	15.47
EC-370773	17.3 (24.57)	28.4 (32.23)	22.88
EC-370823	9.3 (18.19)	22.3 (20.06)	15.70
EC-370929	4.1 (11.78)	8.1 (16.58)	6.14
EC-370932	3.8 (11.31)	3.8 (11.25)	3.86
EC-370867	16.3 (23.81)	26.6(25.89)	21.51
EC-370663	16.0 (23.67)	22.4 (28.28)	19.27
EC-351832	3.7 (11.21)	4.7 (12.49)	4.28
ES-29	16.6 (23.79)	18.7 (25.54)	17.72
ES-115-2-84	9.0 (12.41)	11.3 (19.71)	10.24
ES-123-2-84	10.9 (19.20)	10.5 (18.91)	10.71
ES-135	9.0 (19.20)	15.3 (23.06)	12.22
ES-139-2-84	22.0(28.00)	33.2 (35.17)	27.60
ES-319-2-84	*15.6 (23.21)*	*18.2 (25.20)*	*16.95*
ES-99	16.6 (24.15)	20.4 (26.85)	18.57
ES-1-2-84	18.0 (25.26)	24.5 (29.62)	21.27
DHANERA-1	21.5 (27.07)	27.0 (31.34)	24.32
IS-97	9.7 (18.36)	8.2 (16.66)	9.00
IS-100-B	9.5 (17.83)	9.2 (17.69)	9.38
IS-646-1	9.6 (18.15)	7.8 (16.24)	8.76
ES-379-3-84	7.5 (15.89)	2.8 (09.64)	5.17
RT-103	46.0 (42.71)	41.0 (39.82)	43.35
RT-46	38.4 (38.31)	31.3 (34.04)	34.90
TC-25	52.7 (46.52)	52.3 (46.36)	52.34
VRI-1	57.4 (49.47)	60.2 (50.94)	58.83
SEm ±	2.05	1.40	
C. D. (P =0.05)	5.98	4.10	
CV %	13.2	7.71	

* Angular transformed values

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Short communication

Fatty acid composition in germinating soybean, *Glycine max* Merr. : a non-destructive method to test large breeding populations

Anita Rani, Vineet Kumar and G.S. Chauhan

National Research Centre for Soybean, Khandwa Road, Indore-452 017, MP

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Soybean [*Glycine max* Merr.] oil is the world's leading vegetable oil and represents about 28% of the total worldwide production of vegetable oils. In general, oil from common soybean cultivars consists of 11% palmitic acid (C16:0), 3% stearic acid (C18:0), 23 % oleic acid (C18:1), 53 % linoleic acid (C18:2) and 7 % linolenic acid (C18:3) (Fehr *et al.* 1992). Linolenic acid though a precursor to omega fatty acids is considered as the main culprit for poor shelf life of soybean oil because the rate of oxidation of linolenic acid, linoleic acid and oleic acid are in the ratio of 21.6:10.3:1 (Fatemi and Hammond, 1980). Partial hydrogenation employed at industry level to improve oxidative stability of soybean oil results in the formation of *trans* fatty acids. Hence, breeding efforts are being made to develop soybean varieties with high oleic and low linolenic acid so that oil produced from such soybean has an improved shelf life without hydrogenation (Fehr and Curtiss, 2004).

For making selections in segregating population for desirable fatty acid composition, half seed is taken for analysis while remaining half seed containing embryo is saved for growing next generation (Rahman *et al.*, 2001). Sometimes seed embryos get damaged while dissecting the seed for fatty acid analysis. Damage to embryo can be prevented if fatty acid analysis is done in the cotyledons after germination. Such analysis will be useful only if fatty acid composition of dry seed corresponds with fatty acid composition of cotyledon of germinated seeds. In the present investigation, fatty acid composition of germinating seeds were analysed in three popular soybean genotypes at two germination temperatures to monitor the changes in fatty acid composition during germination.

Seeds of three popular soybean genotypes viz. 'Samrat', 'JS 335' and 'Pb1' were germinated at 25°C and 35°C for 6 days in seed germinator in dark. After every 24 hrs, cotyledons were removed from germinating seeds. Subsequently, cotyledons of seedlings were allowed to dry in a seed drier at 40°C till most of the moisture is eliminated following Maestri *et al.* (1998).

Dried cotyledons from ten seedlings at different stages of germination were ground in a metallic pestle and mortar. Ground flour so obtained was then extracted with petroleum ether (b.p. 60-80°C) in Soxhlet unit for 7 hrs. Percent oil content was calculated by gravimetric method. Data given in table1 are means of determination in three samples.

Oil was extracted from ten independent cotyledons by suspending dry powder of cotyledons in petroleum ether and transesterified in methanol with 1N sodium methoxide as catalyst following Luddy *et al.* (1968). Fatty acid methyl esters (FAMEs) were separated and analyzed by gas chromatograph (GC), Shimadzu GC 17A, using polyethylene glycol packed, SGE BP20 capillary column, with length and internal diameter of 30 meter and 0.32 millimeter, respectively. Oven temperature of the gas chromatograph was programmed at 140°C for 3.6 min, subsequently increased to 170°C at the rate of 13.5°C per minute and maintained for 3.8 min and finally increased to 182°C at the rate of 5°C per minute for best resolution of methyl esters. The temperatures of flame ionization detector (FID) and injector were maintained at 240°C. Nitrogen, the carrier gas used, was maintained at a flow rate of 15 ml/min. Peaks for individual fatty acid methyl esters were identified by comparing the retention times with those of standard methyl esters (procured from Sigma-Aldrich). Data given in table1 for different fatty acids are means of determination in ten samples.

Table1 indicates the changes in oil content and fatty acid composition during germination of soybean seeds at two temperatures. Oil declined in all the three genotypes at both the temperatures with varying rate. As regard to individual fatty acid, there was no change till 120 hrs at both the temperatures in all the genotypes. Among saturated fatty acids, stearic acid (C18:0) increased significantly on 6th day at 35°C as compared to mature seeds in all the genotypes. No change was observed in stearic acid concentration in the cotyledons even on 6th day at a germination temperature of 25°C. With regard to monounsaturated fatty acid i.e. oleic acid (C18:1), it

declined significantly on 6th day in the cotyledons of seedlings developed at 25°C. However, there were no significant differences for this fatty acid between ungerminated seeds and the cotyledons of 6 days' old seedling at a germination temperature of 35°C in all the three genotypes. Furthermore, the three genotypes exhibited a higher level of oleic acid content in the cotyledons of 6 days' old seedling developed at 35°C than at 25°C. As regard to linoleic (C18:2) and linolenic acid (C18:3), there were no significant changes till 120 hrs (5 days) of germination at both the temperature in all the genotypes, however, linoleic acid content increased in all the three genotypes as compared to mature seeds at the germinating temperature of 25°C. No significant differences were observed for linolenic acid, precursor to omega fatty acid, in both the genotypes at both the germination temperatures.

Table 1 Per cent oil content and fatty acid composition in cotyledons of soybean seedlings germinated for different periods at different temperatures

Genotype	Stage of germination (hrs)	% oil	Fatty acid composition at 25°C					% oil	Fatty acid composition at 35°C				
			16:0	18:0	18:1	18:2	18:3		16:0	18:0	18:1	18:2	18:3
Samrat													
	Mature seed	17.50	12.82	3.51	20.53	54.90	7.52	17.50	12.82	3.51	20.53	54.90	7.52
	24	16.4	12.91	3.50	19.50	55.64	7.47	16.42	12.87	3.56	19.62	55.70	7.65
	48	16.53	12.44	3.35	19.42	56.40	7.80	13.33	12.30	3.80	19.75	56.14	7.40
	72	12.33	12.42	3.46	19.61	56.14	7.47	12.53	12.71	3.54	19.46	56.54	7.13
	96	12.23	12.51	3.62	18.67	56.90	7.36	11.39	12.67	3.64	19.83	56.20	7.29
	120	11.52	11.90	3.74	18.54	57.26	7.44	9.93	13.70	3.78	18.78	56.26	7.16
	144	11.49	12.76	3.75	16.78	58.24	7.83	9.91	11.87	4.29	18.80	56. 12	7.31
JS335	Mature seed	18.50	12.20	3.30	23.71	50.03	7.20	18.50	12.20	3.30	23.71	50.03	7.20
	24	16.71	11.51	3.51	24.50	52.74	6.76	16.52	11.21	3.74	24.54	52.42	6.81
	48	16.02	10.87	3.65	24.56	52.72	6.90	15.31	10.62	3.74	25.82	52.00	6.32
	72	14.11	11.51	3.74	24.53	52.61	6.71	13.76	10.00	3.40	24.40	54.65	7.16
	96	13.70	10.75	3.81	24.31	53.30	6.54	11.62	10.11	3.81	25.71	51.74	6.54
	120	12.10	10.62	3.87	23.16	54.00	6.90	10.26	10.40	3.90	25.79	51.80	6.60
	144	11.12	11.46	3.76	19.76	52.01	6.61	9.76	11.62	4.21	25.82	51.21	6.81
Pb1	Mature seed	16.80	14.0	4.13	25.52	49.65	6.71	16.80	14.0	4.13	25.52	49.65	6.71
	24	15.42	14.1	3.92	24.51	50.34	6.62	16.11	14.0	3.92	25.01	50.04	6.63
	48	15.20	13.8	3.94	25.43	50.41	6.83	15.80	13.4	3.81	25.61	50.21	6.85
	72	11.24	14.3	4.05	24.81	49.81	6.51	14.91	14.7	3.90	26.13	51.23	6.78
	96	10.12	14.3	3.91	25.14	50.31	6.84	11.03	14.3	3.77	25.83	52.03	6.94
	120	9.76	13.9	4.32	23.61	52.80	6.21	10.84	14.9	3.82	24.52	52.91	6.57
	144	9.70	13.9	4.02	21.12	54.23	6.84	8.46	14.4	4.61	23.52	53.24	6.23
LSD (P =0.05)		0.85	1.25	0.46	1.73	2.32	0.62	0.87	1.43	0.33	1.83	2.43	0.62

Since there is no significant differences in fatty acid composition of germinating seedlings till five days for any of the fatty acid at any of the two germinating temperature, hence, to avoid the risk of damaging the embryo of the seed, fatty acid composition may be analyzed safely in the cotyledon after germinating for five days. However, stearic acid may be over estimated at 35oC and oleic acid may be under estimated at 25°C after fifth day of germination.

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Short communication

Quality traits of *Crambe abyssinica* collections and comparison of its fatty acid profile with *Brassica* species

S. Mandal, Ranbir Singh, Pallavi Vatsa, Kushal Singh Bisht and M. Singh

Germplasm Evaluation Division, National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110 012

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Crambe abyssinica, family Cruciferae finds its application because of high erucic acid (up to 62%) in seed oil. The utilization potential of *Crambe* seed oil has been described (USDA, 1962; Bruun and Matchett, 1963). Some of the uses for erucic acid and its derivatives are for polyamide fibers, plasticizers, polyesters, alkyl resins, lubricants, surface active agents, water repellents and in the synthesis of new waxes. The *Crambe* fruits with maximum proportion of seed, high seed oil and its high erucic acid proportion are the parameters which directly affect profitability. Like rapeseed-mustard, *Crambe* also contains appreciable amount of glucosinolates. With the application of modern processing techniques, glucosinolates can be removed profitably and seed meal can be used as stock-feed. Keeping all these points in view, efforts were made to introduce *Crambe* lines in crop improvement programmes. Unlike *Crambe*, mustard and rapeseeds are used for edible purposes and seed oil with lower erucic acid level is preferred because of its anti-nutritional properties. In addition to low erucic acid, edible *Brassica* seed oil with higher level of oleic acid is preferred both from nutritional as well as keeping quality point of view.

In the present communication, some quality traits like seed oil, protein, seed (%) of the fruit and fruit oil were determined in 45 exotic crambe lines. Fatty acid profiles of the seed oil were also studied and associations of different fatty acid with erucic level were established. Similar studies were also performed with 208 germplasm collections of rapeseed-mustard for comparison of erucic, oleic acid relationship.

A total of 45 exotic *Crambe abyssinica* collections were grown at IARI Farm during *Rabi*, 2002-2003. Another lot of 208 rapeseed-mustard, built up through introduction, exchange and exploration activities of NBPGR, New Delhi, were grown at the experimental farm of NBPGR, New Delhi. Three rows of each accession were planted following normal management practices. Seeds were harvested when plants attained complete maturity. The data on five plants in each genotype were recorded. The mature *Crambe* fruits were first taken for oil estimation and for establishment of Seed (%) of the fruit. Seeds of the *Crambe* were later used for oil, protein, 1000 seed weight and fatty acid analysis. For *Brassica* samples, seeds were used for oil and fatty acid analysis.

Nitrogen content of the whole *Crambe* seeds was determined by conventional Kjeldahl method with Kjeltec analyzer (Model-2300) from Foss Tecator, Sweden. Factor 6.25 was used to convert nitrogen to protein. Total oil content of the seed samples (dried at 108°C for 16-18 hrs) were determined by a non-destructive method using a Newport NMR analyzer (model-4000) from Oxford Analytical Instruments Ltd. U.K. after calibrating with pure seed oil.

Recently developed Gas Liquid Chromatography (GLC) method (Mandal *et al.*, 2002) was followed for the determination of fatty acid profile of the oil using Hewlett Packard gas chromatograph, model 6890 equipped with flame ionization detector (FID). The injector and detector temperatures were 260°C and 275°C respectively. Oven temperature was programmed from 150°C holding at 1 min. to 210°C at the rate of 15°C/min., followed by 210°C to 250°C at the rate of 5°C/min. for 12 min. Peak integration was performed applying HP3398A software.

Table 1 Quality traits of 45 accessions of exotic *Crambe*

Trait	Range	Mean
Fruit oil (%)	13.61 - 31.02	23.13
Seed (%) of the fruit	29.61 - 68.93	54.96
Seed oil (%)	27.91 - 44.95	38.91
Seed protein (%)	23.62 - 30.47	27.76
1000 seed weight (g)	1.83 - 3.66	3.10

Fairly good variation was observed with respect to seed weight and husk-seed ratio of the fruits (Table 1). *Crambe* fruits contained about 45% husk. The average seed yield and oil content was 1400 kg/ha and 38.91% respectively. Because of low seed yield, the average oil yield was only 544 kg/ha in comparison to average of 760 kg/ha oil yield recorded for other rapeseed-mustard lines. Hirsinger (1989) has reported *Crambe* yields upto 2000 kg/ha of seed with an oil content of 26-38%. In comparison to other *Brassica* seed oil, *Crambe* oil was found to contain less concentration of eicosenoic acid (1-3%) and higher concentration of both the oleic (18.22%) and erucic acid

(60.20%). At the minimum level of 44-45% erucic acid, the oleic acid content of *Crambe* seed oil was found to vary within the range of 23.6 to 31.22%, and at the higher level of 61.4 to 64.5% erucic acid, the oleic proportion varied in the range of 13-17.6%.

In the present *Crambe* lines, the combined oleic and erucic acid concentration ranged from 65.66 to 80.80% with the mean value 73.64%. Thus mean concentration is definitely higher side as compared to other *Brassica* species Collections under *Brassica napus* lines with erucic acid level of less than 10%, the range of corresponding combine percentages was only within the narrow scale of 65.24-67.00%. This is mainly due to high negative association exist between erucic acid and oleic acid in *B. napus* seed oil particularly in low erucic acid containing lines in comparison to *Crambe* seed oil. Low erucic acid containing lines (<10%) showed higher corresponding mean value than the normal indigenous *B. napus* line with comparatively high erucic acid level.

Mandal *et al.* (2002), have determined correlation value ® of -0.980** for *B. napus* collections. For *B. juncea*, yellow sarson, toria, brown sarson, the corresponding values were -0.922**, -0.395*, 0.025, -0.608* respectively. Correlation ®) value of -0.558* has been established for the association of erucic and oleic acid concentration in the oil of present *Crambe* lines.

The association ® between other fatty acids namely palmitic, stearic, lindleic, linolenic, eicosenoic with erucic acid in *Crambe* oil was -0.507**, +0.148, -0.226, 0.022, -0.133, respectively.

* = significant at P=0.05; ** = significant at P=0.01

Table 2 Oleic and erucic acid content in the oil of different species of Brassica and Crambe seed

Species	No. of accessions	*Oleic acid (area %)*		*Erucic acid (area %)*		Combined percentage of oleic and erucic acid	
		Range	Mean	Range	Mean	Range	Mean
B. juncea	47	9.49 - 19.15	13.73	38.76 - 52.40	48.17	56.13 – 63.51	62.06
B. napus high Erucic acid >10%	22	19.29 – 51.56	31.42	11.39 - 44.49	29.94	56.53 – 67.67	61.59
B. napus low Erucic acid <10%	19	55.24 - 65.00	61.38	2.00 – 10.00	5.14	65.24 – 67.00	66.52
B. rapa var. Yellow Sarson	56	10.78 - 18.98	14.78	45.88 – 57.08	51.68	58.87 – 71.31	65.26
B. rapa var. Toria	28	11.97 - 20.20	15.48	40.71 – 51.50	47.30	55.42 – 67.70	62.76
B. rapa var. Brown Sarson	18	8.74 - 21.57	13.14	39.79 – 53.25	47.25	55.42 – 65.70	61.46
B. nigra	9	8.13 - 16.52	11.37	35.93 – 53.46	43.96	46.83 – 63.16	51.20
B. carinata	9	11.26 - 16.87	14.37	37.21 – 55.69	45.63	51.45 – 70.49	59.75
Crambe abyssinica	45	13.00 – 31.22	18.22	45.16 – 62.20	60.20	65.66 – 80.80	73.64

Though the negative association between oleic and erucic acid in Crambe oil is significant but unlike low erucic acid *B. napus* collections, no *Crambe abyssinica* line containing very high erucic acid and very low oleic acid (<13%) in the oil have been recorded. Such type of value added *Crambe* lines would increase the economical acceptability of species for other industrial purposes.

Seed protein of the present *Crambe* accessions was ranged from 23 to 31% with the mean value 27%. In our earlier study (Mandal *et al.*, 1993) with different species of Brassica seed, the mean seed protein percentages of 25.88, 23.35, 22.74 and 22.25 were established for *B. carinata*, yellow sarson, *B. juncea* and *B. napus* respectively. This high protein value in *Crambe* seed may prove economical if appropriate technique to remove glucosinolate is followed for its use as cattle feed.

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Announcement

The Indian Society of Oilseeds Research (ISOR) is happy to announce the organization of National Seminar on **"Changing Global Vegetable Oils Scenario: Issues and Challenges Before India" during January 29-31, 2007** at Hyderabad.

The Seminar covers eight themes, *viz.*, Integrated resource management, Vegetable oils as biofuels, Current trends in pest management, Policy framework for oilseed sector, Genetic diversity and gene mining, Post-harvest management: Processing and value addition, Non-conventional vegetable oils and Informatics & transfer of technology.

During the Seminar invited lectures in each theme will be organized on topics of interest to the oilseed sector by eminent persons from all over India. The ISOR welcomes the participation of all those involved in oilseeds research, development, production, processing, policy making, marketing, post-harvest management, *etc.* Those desirous of contributing papers are requested to send an extended summary of their contribution not exceeding 3-4 pages including tables (along with diskette) so as to reach on or before 31-10-2006 to:

Dr. D. M. Hegde
Organising Secretary, ISOR National Seminar,
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