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Heterosis in relation to genetic divergence in parental lines of sunflower, *Helianthus annuus* L.*

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Abstract

Evaluation of 60 hybrids derived from crossing six A lines and 10 restorers in a line x tester programme was carried out to know the extent of genetic divergence among parents and crosses and to relate with heterosis. The results revealed that the parents and hybrids were grouped in 12 clusters indicating substantial variability in the material studied. Almost all the A lines (corresponding B lines) were grouped in cluster I, whereas R lines in clusters II, IV, V, VI, VII, X and XII indicating that R lines are genetically more divergent than A lines. The D^2 values ranged from 97.93 (cluster IV) to 170.16 (cluster XI) supporting the existence of genetic variability in the material. Further, classification of parents and hybrids into four divergence classes revealed that crossing of parents with moderate genetic divergence from DC_2 and DC_3 classes resulted in higher frequency of hybrids with significant heterosis over mid parent of which (CMS-234A x NDOL-3) x RHA-857 (NB), CMS-234A x NDOL-3) x 6.D-1 (Br) and CSM-234A x DSF-2) x RHA-265 (NB) excelled. However, crossing of parents belonging to extreme genetic divergence classes DC_1 and DC_4 resulted in hybrids with non-significant heterosis.

Key words: Sunflower, heterosis, D^2 values, divergence

Introduction

Sunflower being a highly cross pollinated crop is ideal for exploitation of heterosis. The concerted efforts in this direction to develop and evaluate hybrids using different CMS and fertility restorer lines have been made. Plant breeders have extensively used and exploited heterosis to improve seed yield in many crops, more so in sunflower. The value of hybrids and importance of heterosis breeding was recognized very early in sunflower as they are generally more vigorous, uniform and self fertile with high productivity. However, genetic diversity of parents is equally important as pointed by Arunachalam *et al.* (1984) in groundnut and Behl *et al.* (1985) in sunflower. The above findings have established a close correspondence between the genetic divergence and magnitude of heterosis. It is also being reported that hybrids from genetically diverse parents manifest greater heterosis than that of more closely related parents (Cheres *et al.*, 2000). This seems to be true not always as there are reports suggesting that requisite magnitude of heterosis can be realized when parents with moderate divergence are involved in crosses (Arunachalam *et al.*, 1984 and Behl *et al.*, 1985) and some time the expected heterosis may not be realized when one looks for highly divergent parents for crosses (Cress, 1966), as there may be existence of non correspondence between parents and hybrids on account of environmental factors.

With this background, the present investigation was designed to elucidate the kind of relationship that exists between heterosis and parental diversity in sunflower.

Materials and methods

Investigations were carried out using six CMS lines *viz.*, (VRF x NDOL-2), (851A x NDOL-2), (4546A x DSF-2), (234A x DSF-2), (234A x NDOL-3) and (VRF x DSF-2) in crosses with ten Restorers *viz.*, RHA-274 (Br), RHA-274 (NB), RHA-298 (NB), RHA-857 (NB), RHA-857 (BR), IX-11 (NB), X-13 (NB), V-20 (Br), RHA-265 (NB) and 6 D-1 (Br), DSF-2, NDOL-2 and NDOL-3 to produce 60 F_1 hybrids in a line x tester fashion at the Oilseeds Scheme, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during rainy season of 2007. These 60 hybrids along with six B lines of corresponding A lines and ten restorers were evaluated in a Randomized Block Design with two replications in summer 2007. Each genotype was provided plot size consisting of single row of 4 metre length with inter and intra row spacing of 60 cm and 30 cm, respectively. Two to three seeds treated with Imidacloprid (@ 5 g/kg of seeds were dibbled/hill, after applying half the recommended dose of N and entire P and K as basal. The remaining N was top dressed when the crop was around 35 days old followed by an inter culture. Thinning excess seedlings to maintain one healthy plant/hill was attended 15 days after complete emergence of the experimental crop. All the recommended agronomic practices were followed to raise a successful experimental crop. The observations were recorded from five random

* Part of Ph.D. (Agril.) Thesis submitted by the senior author to the Department of Genetics and Plant Breeding, UAS, Dharwad-580 005.

but competitive plants on 11 characters *viz.*, days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), number of leaves/plant, test weight (g), hull content (%), volume weight (g/100 cc), per cent seed filling, seed yield (g/plant) and oil content. After computing means, the data was subjected to D^2 analysis. The genotypes were grouped into different clusters according to Toucher's method and inter and intra cluster distances were calculated. Heterosis was estimated as the improvement of F_1 over better parent for each character. The method devised by Arunachalam *et al.* (1984) was used to delineate parental divergence in four divergent classes (DC). To take into account the variable magnitude of variation in parental divergence, the mean (M) and standard deviation (S), the values of divergence were calculated. The minimum (X) and maximum(Y) values among D^2 values between parents being determined using 'M' and 'S' and the range of D^2 values is being divided into four divergence classes.

Results and discussion

The results of genetic diversity analysis (Table1) revealed that 76 genotypes comprising both parents and their F1's were scattered in as many as 12 clusters. Thus number of clusters formed reflected on genetic divergence in the material. It is interesting to note that all six A lines appeared in cluster I, indicating narrow genetic divergence among them.

Table 1 Clusters formation and genotype composition of the clusters in sunflower

Cluster Number	Genotypes per cluster	Parents and hybrids clustered	Parents/ hybrid
I	08	(VRF x NDOL-2), 851A x NDOL-2), (4546A x DSF-2) (234A x DSF-2), (234A x NDOL-3) , (VRF x DSF-2) (VRF x NDOL-2) x RHA-857(Br), (VRF x NDOL-2) x RHA-IX-11(NB)	A lines A lines Hybrids
II	08	(4546A x DSF-2)x RHA-V-20 (Br), (234A x NDOL-3) x RHA-X-13 (NB) (VRF x NDOL-2) x RHA 265(NB), (851A x NDOL-2) x RHA 265 (NB) (VRF x DSF-2) x RHA-X-13 (NB), (234A x DSF-2) x RHA-V-20 (Br) RHA 265 (NB) , RHA- 298 (NB)	Hybrids Hybrids Hybrids Restorers
III	12	(VRF x NDOL-2) x RHA-274(NB), (851A x NDOL-2) x RHA-274(NB) (851A x NDOL-2) x RHA-857(Br), (4546A x DSF-2) x RHA-274(Br) (4546A x DSF-2) x RHA-857(Br), (234A x DSF-2) x RHA-857(Br) (234A x DSF-2) x RHA-274(Br), (234A x DSF-2) x 6D-1(Br) (234A x NDOL-3)xRHA-857(NB), (234A x NDOL-3) x 6D-1(Br) (VRF x DSF-2)xRHA- 298 (NB), (VRF x DSF-2) x RHA- 265 (NB)	Hybrids
IV	05	RHA-274(Br) , RHA-X-13 (NB) (VRF x NDOL-2) x 6D-1(Br), (4546A x DSF-2) x RHA 265 (NB) (234A x NDOL-3)xRHA-V-20 (Br)	Restorers Hybrids Hybrid
V	13	RHA-V-20 (Br) (VRF x NDOL-2) x RHA-857(Br), (851A x NDOL-2) x RHA-274(Br) (851A x NDOL-2)xRHA- 298 (NB), (851A x NDOL-2) x RHA-V-20 (Br) (4546A x DSF-2)x RHA-X-11(NB), (4546A x DSF-2) x 6D-1(Br) (234A x DSF-2) x RHA-274(NB), (234A x DSF-2) x RHA-X-13 (NB) (234A x NDOL-3) x RHA- 265 (NB), (234A x NDOL-3) x RHA- 298 (NB) (VRF x DSF-2) x RHA- 274(Br), (VRF x DSF-2) x RHA-IX-11(NB)	Restorer Hybrids Hybrids Hybrids Hybrids Hybrids Hybrids
VI	08	RHA-274(NB) (VRF x NDOL-2) x RHA- 298 (NB), (851A x NDOL-2) x RHA-IX-11(NB) (4546A x DSF-2) x RHA-274(NB), (234A x DSF-2) x RHA-857(Br) (234A x NDOL-3) x RHA-274(Br), (VRF x DSF-2) x RHA-857(NB) (VRF x DSF-2) x 6D-1(Br)	Restorer Hybrids Hybrids Hybrid
VII	07	RHA-IX-11(NB) (VRF x NDOL-2)xRHA-V-20 (Br), (851A x NDOL-2) x RHA-X-13 (NB) (4546A x DSF-2)xRHA-X-13 (NB), (234A x DSF-2) x RHA-X-11(NB) (234A x NDOL-3)xRHA-X-11(NB), (VRF x DSF-2) x RHA-857(Br)	Restorer Hybrids Hybrids Hybrids
VIII	03	(851A x NDOL-2) x 6D-1(Br), (234A x DSF-2) x RHA- 265 (NB) (VRF x DSF-2) x RHA-V-20 (Br)	Hybrids
IX	06	(VRF x NDOL-2) x RHA-857(NB), (851A x NDOL-2) x RHA-857(NB) (4546A x DSF-2) x RHA- 298 (NB), (234A x DSF-2) x RHA- 298 (NB) (234A x NDOL-3) x RHA-274(NB), (VRF x DSF-2) x RHA-274(NB)	Hybrids
X	02	RHA-274(Br) (VRF x NDOL-2) x RHA-274(Br)	Restorer Hybrid
XI	02	(4546A x DSF-2) x RHA-857(NB), (234A x NDOL-3) x RHA- 298 (NB)	Hybrids
XII	02	RHA-857(NB), 6D-1(Br)	Retorers

Table 2 D^2 values and divergence class of parents related to heterosis over mid-parent and better parent in sixty crosses in sunflower

Crosses	Corresponding D^2 values between parents	Divergence class	Mid parent heterosis for seed yield/plant	Better parent heterosis for seed yield/plant
(VRF x NDOL-2) x RHA-274 (Br)	408.16	DC_1	45.56 **	16.13
(VRF x NDOL-2) x RHA-274 (NB)	47.55	DC_4	19.41	5.43
(VRF x NDOL-2) x RHA-298 (NB)	255.98	DC_2	0.83	-2.65
(VRF x NDOL-2) x RHA-857 (NB)	174.62	DC_3	-2.11	-6.28
(VRF x NDOL-2) x RHA-857 (Br)	206.47	DC_3	18.14	-0.09
(VRF x NDOL-2) x RHAIX-11 (NB)	128.50	DC_3	10.44	2.84
(VRF x NDOL-2)X-13 (NB)	143.43	DC_3	3.82	-11.10
(VRF x NDOL-2) x RHAV20 (Br)	442.92	DC_1	19.50	-4.97
(VRF x NDOL-2) x RHA-26 (Br)	144.23	DC_3	15.57	13.07
(VRF x NDOL-2) x 6.D-1	305.14	DC_2	39.48 **	12.37
(851A x NDOL-2) x RHA-274 (Br)	378.07	DC_2	18.35	-2.66
(851A x NDOL-2) x RHA-274 (NB)	40.74	DC_4	14.26	4.50
(851A x NDOL-2) x RHA-298 (NB)	288.01	DC_2	21.78 *	13.24
(851A x NDOL-2) x RHA-857 (NB)	193.01	DC_3	0.91	0.43
(851A x NDOL-2) x RHA-857 (Br)	186.77	DC_3	16.07	1.48
(851A x NDOL-2)IX-11 (NB)	151.60	DC_3	3.95	-6.63
(851A x NDOL-2)X-13 (NB)	128.48	DC_3	40.12 **	24.11
(851A x NDOL-2) x RHAV20 (Br)	432.04	DC_1	40.22 **	14.92
(851A x NDOL-2) x RHA-265 (NB)	161.86	DC_3	-3.50	-9.12
(851A x NDOL-2) x 6.D-1	316.18	DC_2	49.15 **	23.93
(4546A x DSF-2) x RHA-274 (Br)	573.47	DC_1	12.25	-16.43
(4546A x DSF-2) x RHA-274 (NB)	156.47	DC_3	-0.96	-19.34 *
(4546A x DSF-2) x RHA-298 (NB)	215.17	DC_3	-7.01	-12.50
(4546A x DSF-2) x RHA-857 (NB)	259.90	DC_2	-19.42 *	-29.45 **
(4546A x DSF-2) x RHA-857 (Br)	99.52	DC_4	6.15	-16.80
(4546A x DSF-2)IX-11 (NB)	247.02	DC_2	-0.04	-2.44
(4546A x DSF-2)X-13 (NB)	530.71	DC_1	-16.40	-33.74 **
(4546A x DSF-2) x RHAV20 (Br)	211.22	DC_3	7.68	-20.06 *
(4546A x DSF-2) x RHA-265 (NB)	407.19	DC_1	-25.43 **	-30.72 **
(4546A x DSF-2) x 6.D-1	490.40	DC_1	-7.36	-30.43 **
(234A x DSF-2) x RHA-274 (Br)	186.93	DC_3	36.43 **	13.72
(234A x DSF-2) x RHA-274 (NB)	93.33	DC_4	-5.46	-12.19
(234A x DSF-2) x RHA-298 (NB)	104.78	DC_3	-12.82	-20.18
(234A x DSF-2) x RHA-857 (NB)	188.97	DC_3	-2.60	-3.76
(234A x DSF-2) x RHA-857 (Br)	67.77	DC_4	6.89	-5.18
(234A x DSF-2)X-11 (NB)	280.77	DC_2	-3.86	-14.92
(234A x DSF-2)X-13 (NB)	280.78	DC_2	13.11	1.68
(234A x DSF-2) x RHAV20 (Br)	351.38	DC_2	9.91	-8.71
(234A x DSF-2) x RHA-265 (NB)	157.06	DC_3	30.17 **	20.68
(234A x DSF-2) x 6.D-1	266.24	DC_2	30.05 *	9.54
(234A x NDOL-3) x RHA-274 (Br)	207.70	DC_3	-0.65	-18.02
(234A x NDOL-3) x RHA-274 (NB)	51.25	DC_4	27.16 *	16.73
(234A x NDOL-3) x RHA-298 (NB)	317.36	DC_2	0.06	-7.31
(234A x NDOL-3) x RHA-857 (NB)	139.99	DC_3	38.90 **	38.81 **
(234A x NDOL-3) x RHA-857 (Br)	85.09	DC_4	4.11	-8.66
(234A x NDOL-3)X-11 (NB)	202.41	DC_3	-13.77	-22.83 *
(234A x NDOL-3)X-13 (NB)	108.81	DC_3	-4.78	-15.36
(234A x NDOL-3) x RHAV20 (Br)	232.30	DC_3	19.83	-1.47
(234A x NDOL-3) x RHA-265 (NB)	192.07	DC_3	26.09 *	18.29
(234A x NDOL-3) x 6.D-1	187.97	DC_3	61.70 **	34.81 **
(VRF x DSF-2) x RHA-274 (Br)	663.32	DC_1	17.97	-7.73
(VRF x DSF-2) x RHA-274 (NB)	206.41	DC_3	10.25	-4.88
(VRF x DSF-2) x RHA-298 (NB)	149.73	DC_3	-1.62	-2.48
(VRF x DSF-2) x RHA857 (NB)	241.41	DC_3	-17.36	-22.87 *
(VRF x DSF-2) x RHA-857 (Br)	300.76	DC_2	-3.52	-20.17
(VRF x DSF-2) x RHAIX-11 (NB)	86.36	DC_4	9.07	4.17
(VRF x DSF-2)X-13 (NB)	331.25	DC_2	-13.72	-27.74 *
(VRF x DSF-2) x RHAV20 (Br)	551.18	DC_1	-3.39	-24.68 *
(VRF x DSF-2) x RHA-265 (NB)	173.31	DC_3	-34.86 **	-35.18 **
(VRF x DSF-2) x 6.D-1	359.78	DC_2	1.26	-20.05

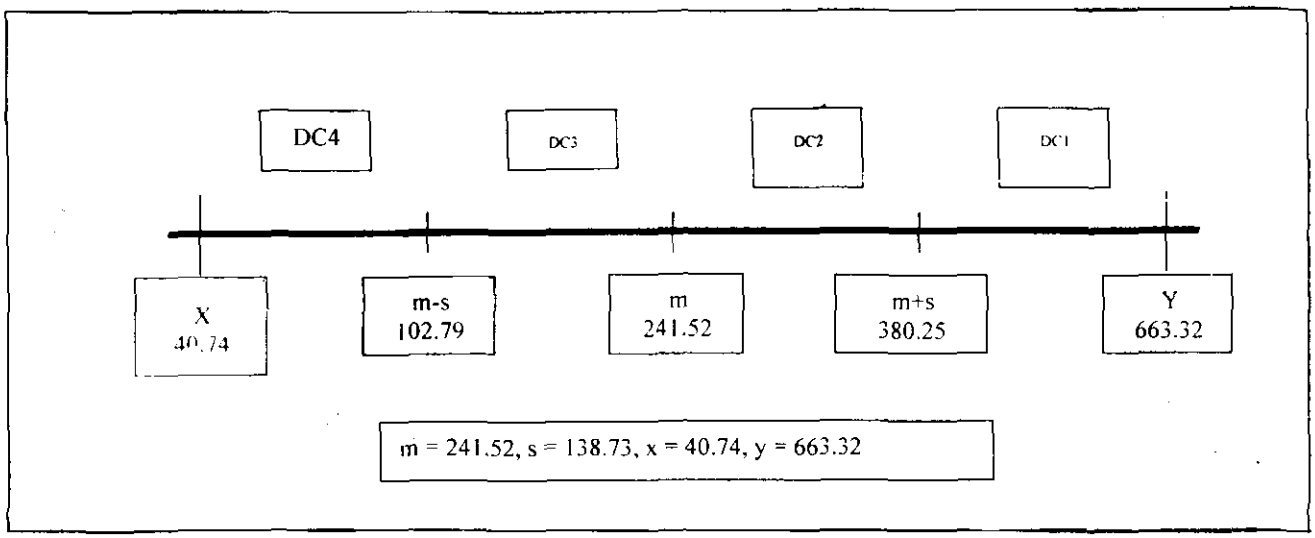

Fig. 1. Classification of parental divergence

This can be attributed to single source of cytoplasm currently employed in sunflower as well as genetically related inbreds in development of CMS lines. Such a narrow genetic variability among A lines appearing within the clusters has also been reported earlier (Teklewold *et al.*, 2000; Ramasubrhamanyam *et al.*, 2003 and Srinivas *et al.*, 2006). On the other hand, the R lines found to have been grouped in different clusters *viz.*, II, IV, V, VI, VII, X and XII indicating that they are genetically more divergent compared to A lines. Thus, the results clearly reveal that there is a need to diversify A lines for realizing significant standard heterosis. As regards to grouping of 60 hybrids, two clusters III and V formed the major clusters each containing 12 hybrids, which was followed by clusters VI with seven hybrids, clusters II, VII and IX with six hybrids each. The clusters IV had three hybrids, while I and XI two hybrids each. This suggests that the diversity existed even among hybrids in spite of involving genetically similar A lines, perhaps contributed from divergent R lines. The clustering pattern of hybrids is known to be influenced by their parents because of close affinity between the parents and their hybrids (Chaudhary and Singh, 1975).

The crosses were grouped into four divergence classes (Fig. 1) based on parental divergence (Arunachalam *et al.*, 1984), wherein the D^2 values between parental combinations ranged from 40.74 to 663.32. As for genetic divergence of parents in relation to heterosis is considered, the crosses irrespective of the traits appeared in greater frequency in DC_2 and DC_3 compared to DC_1 and DC_4 suggesting that moderate divergence prevailed among parents and crosses (Madrap and Makne, 1993; Lalitha Reddy *et al.*, 2000). As regards to number of hybrids exhibiting significant heterosis over mid parent in different classes it was observed that four hybrids appeared in DC_2, six in DC_3, two hybrids in DC_1 and only one in DC_4. Thus, DC_2 and DC_3 classes together (moderate divergence) had ten hybrids when compared to three in DC_1 and DC_4 (extreme divergence). This indicates that parents showing moderate genetic divergence can produce higher frequency of heterotic hybrids, which is in agreement with the earlier studies of Arunachalam *et al.* (1984) and Behl *et al.* (1985). Out of 13 hybrids revealing significant heterosis over mid parent, three hybrids *viz.*, (CMS-234A x NDOL-3) x RHA-857 (NB), CMS-234A x NDOL-3) x 6 D1 (Br) and CSM-234A x DSF-2) x RHA-265 (NB), were superior in better parent heterosis (Table 2). So also, the commercial check hybrids KBSH-1, KBSH-44 and DSH-1 exhibited higher standard heterosis and the parents of these hybrids were gtouped in moderate divergence classes. The above results clearly demonstrate that there is definite relationship between magnitude of genetic divergence of the parents involved and frequency of heterotic hybrids. On the other hand, the hybrids (CMS-851A x NDOL-2) x RHA-274 (NB) and (CMS-VRF x DSF-2) x RHA-274 (Br) were noticed in low and high divergence classes, respectively, as also their parents. However, relating heterosis with divergence is being contradicted by the reports of Cress (1966) as observed from non-correspondence between parental divergence and heterosis of hybrids in their studies. Although, heterosis is the function of genetic diversity, the positive relationship between heterosis and parental distance depends on several factors including availability of optimum environment for expression of heterosis and extent of internal balance of various components of heterosis. Thus, the present studies clearly suggest that the parents with moderate genetic divergence when crossed are expected to throw heterotic hybrids in higher number in sunflower. Further, the studies point towards diversification of A lines for realizing higher standard heterosis in the experimental hybrids.

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Heterosis and combining ability for seed yield, oil content and other quantitative traits in sunflower, *Helianthus annuus* L.*

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Abstract

The genetic analysis of line x tester crosses forming 30 hybrids from five CMS lines and six restorers revealed that SCA variances were predominant in the inheritance of seed yield, oil content and for most of the quantitative traits indicating the role of non-additive genes. The parents CMS 17 A and DCMS 51A found to be good general combiners for seed yield, hull content, volume weight, number of filled seeds, 100 seed weight, days to maturity, number of leaves/plant, head diameter, plant height, days to flowering and oil content, while CMS 234 A was a good general combiner for hull content, oil content and volume weight. The tester RHA-6D-1 exhibited high *gca* for 100-seed weight, per cent seed filling and oil content, while R-298 for number of filled seeds/head, volume weight and seed yield. The hybrid CMS 234A x RHA 95-C-1 had significant *sca* effects for seed yield and number of filled seeds/head. It also shown the highest better parental heterosis followed by CMS 234 A x RHA-6D-1, CMS 234 A x RHA-271, CMS 234 A x R-64 and CMS 234 A x R-298 for seed yield. All these hybrids found to have CMS 234 A as one of the parents and both parents in these crosses had low gca effects. The hybrids CMS 17 A x R-298, CMS 103 A x RHA-272, CMS 4546 A x RHA-271 and CMS 4546 A x RHA-272 exhibited significant better parental heterosis for oil content. However, none of the hybrids expressed positive and significant heterosis for both seed yield and oil content.

Key words: Line x tester, heterosis, combining ability

Introduction

Sunflower is an important oilseed crop which can be grown in varied climatic and soil conditions in any season of the year. A high degree of cross pollination coupled with availability of efficient cytoplasmic male sterile and restorer systems offers considerable scope for commercial exploitation of heterosis. The development and release of first ever sunflower hybrid BSH-1 (Seetharam *et al.*, 1980) using male sterility system gave a fillip to large scale cultivation in India. The hybrids synthesized and released both by public and private for commercial cultivation are predominantly Single Crosses (SC), where uniformity is a distinct advantage. The knowledge on the combining ability of parents, nature of gene action governing seed yield and its component characters and magnitude of heterosis are important for commercial exploitation of heterosis (Rajanna *et al.*, 2001). An attempt has been made in the present investigations to know the extent of standard heterosis and combining ability of parents and crosses for important component traits.

Materials and methods

Five CMS lines *viz.*, CMS 234 A, CMS 4546 A, CMS 17 A, CMS 103 A and DCMS-51A were crossed with six restorer lines *viz.*, RHA-6D-1, RHA-95-C-1, R-298, R-64, RHA-271 and RHA-272 in L x T fashion to generate 30 single cross hybrids during *kharif* 2005. The hybrids were evaluated along with 11 parents during *kharif* 2006 at MARS, UAS, and Dharwad in a Randomized Complete Block Design with three replications. Each genotype was represented by three rows of 3 m length with inter and intra row spacing of 60 cm and 30cm, respectively. All the recommended agronomic practices were followed to raise the crop successfully. Observations were recorded on five random but competitive plants for 12 quantitative characters *viz.*, days to 50% flowering, plant height, head diameter, number of leaves/plant, days to maturity, 100 seed weight, per cent seed filling, number of filled seeds/head, volume weight, hull content, oil content and seed yield/plant. Mean values were subjected to line x tester analysis to estimate general combining ability (*gca*) and specific combining ability (*sca*) effects and their respective variances. The significance of heterosis was tested by comparing the estimates against standard errors using 't' test

Results and discussion

The analysis of variance for combining ability (Table 1) revealed that significant differences existed among CMS lines for all the characters, while among restorers for days to flowering, plant height, number of leaves/plant, days to maturity and volume weight indicating presence of

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considerable variability in the material. The line x tester interactions were highly significant for all the characters except days to 50% flowering and number of leaves/plant indicating that lines and testers have nick well ability in the hybrids synthesized and in turn in the expression of heterosis and combining ability. The variances due to specific combining ability (SCA) were higher than that of general combining ability (GCA) for most of the characters studied except days to flowering, which indicates that these characters are influenced by non-additive genes in their inheritance and suggest for exploitation through heterosis breeding. The predominant role of non-additive component of variance in the inheritance of seed yield, oil content and yield related traits has also been reported by Vara Prasad *et al.* (2006), Rukmini Devi *et al.* (2005) and Parameswari *et al.* (2004).

Among different CMS lines used in the development of hybrids, two lines CMS 17 A (parent of KBSH 44) and DCMS 51 A observed to be as good general combiners (Table 2) for number of traits such as seed yield/plant, hull content, volume weight, number of filled seeds, 100 seed weight, days to maturity, number of leaves/plant, head diameter and plant height. This amply suggests that these lines have been bred for good *gca* for more than one trait. However, no parent appeared to be a good general combiner for important traits like seed yield and oil content except DCMS 51A and leads to the opinion that it can be extensively used in crosses whenever the objective is to improve seed yield and oil content simultaneously. CMS 234 A, the parent of KBSH 1 appeared to be a good general combiner for hull content, oil content and volume weight but not for seed yield. It is also a good general combiner for days to 50% flowering, days to maturity and number of leaves/plant. The line CMS 103 A (parent of RSFH 1) is a good combiner for hull content, whereas CMS 4546 A is a poor combiner in respect of majority of the traits studied, implying that they may not yield heterotic hybrids. The study clearly revealed that CMS 17 A, DCMS 51 A and CMS 234 A are the potential CMS lines for developing experimental with superior heterosis for seed yield and oil content. Among the restorers, RHA-6D-1 exhibited high *gca* for 100 seed weight, per cent seed filling and oil content, while R-298 for number of filled seeds/head, volume weight and seed yield and R-64 for days to 50% flowering, plant height and days to maturity and these findings are in accordance with the earlier reports by Shekhar *et al.* (2000) and Madhavi Latha *et al.* (2005). Irrespective of the CMS or R lines, the characters are known to be influenced by additive genes, which suggest that the new parental lines can be developed from the heterotic pools having good general combining ability.

Among various hybrids studied, CMS 234A x RHA 95-C-1 expressed significant *sca* effects (Table 2) for seed yield and number of filled seeds/head, however, the parents involved in the cross were poor general combiners. The possibility of getting crosses with significant *sca* involving poor general combiners for a given trait has been reported earlier (Radhika *et al.*, 2001; and Uttam *et al.*, 2005). The hybrids CMS 17A x R-298 and CMS 103 A x RHA 272 observed to be good specific combiners for oil content, while CMS 234 A x R-64 and CMS 4546A x RHA 95-C-1 for per cent seed filling and in all the crosses parents involved exhibited L x L *gca* effects. The hybrid CMS 234A x RHA 95-C-1 was a good specific combiner for seed yield, per cent seed filling and number of filled seeds. It is interesting to note that the parents with good *gca* for a given trait may not end up always in significant *sca* of the crosses.

Table 1 Estimates of general combining ability (*gca*) effects of parents for 12 characters in sunflower

Source	Days to 50% flowering	Plant height (cm)	Head diameter (cm)	No. of leaves/ plant	Days to maturity	100 seed weight (g)	% seed filling	No. of filled seeds/head	Volume weight (g/100 cc)	Hull content (%)	Oil content (%)	Seed yield/ plant (g)
Lines												
CMS 234A	-2.02 **	-1.71	-0.73 **	1.47 **	-2.67 **	-0.49 **	-0.94	-36.87 **	1.17 *	-2.27**	0.46	-0.61
CMS 4546A	-3.02 **	-10.61 **	-1.24 **	-3.05 **	-2.83 **	-0.20 *	-1.68	-36.34 **	-1.01	-0.42**	-0.01	-4.33 **
CMS 17A	2.59 **	16.52 **	0.69 **	1.90 **	3.78 **	0.86 **	-1.09	80.78 **	2.89 **	4.67**	-2.40 **	4.42 **
CMS 103A	0.26	-26.84 **	0.22	-1.64 **	-0.17	-0.60 **	-1.51	-51.92 **	-4.24 **	1.42**	0.05	-2.59
DCMS 51A	2.20 **	22.64 **	1.06 **	1.33 **	1.89 **	0.43 **	5.22 **	44.35 **	1.20 *	-3.4**	1.90 **	3.12 *
SE (Si)	0.271	1.4482	0.1735	0.4234	0.3846	0.0891	1.1343	9.4195	0.5372	0.1469	0.2518	1.3685
Testers												
RHA 6D-1	0.01	0.12	-0.32	-1.19 *	1.53 **	0.25 *	3.22 *	17.02	0.92	0.81**	1.32 **	0.03
RHA-95-C-1	0.74 *	11.27 **	0.09	-0.31	4.33 **	-0.10	1.54	-4.80	1.15	2.39**	0.10	0.15
R-298	-3.12 **	-7.85 **	0.11	0.14	-4.80 **	0.18	1.98	34.05 **	1.75 **	-0.75**	-1.06 **	4.23 **
R-64	4.88 **	7.14 **	0.34	-1.15 *	6.13 **	-0.10	-2.16	-32.99 **	-4.72 **	-0.46**	-0.77 **	-4.77 **
RHA-271	-0.92 **	-5.20 **	-0.13	1.64 **	-4.53 **	-0.34 **	-2.25	-15.26	0.29	-2.14**	0.39	1.35
RHA-272	-1.59 **	-5.48 **	-0.09	0.88	-2.67 **	0.10	-2.33	1.98	0.63	0.15	0.02	-1.01
SE (Sj)	0.2968	1.5864	0.1901	0.4638	0.4213	0.0976	1.2426	10.31866	0.5884	0.1609	0.2758	1.4991

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

Table 2 Selected crosses with superior heterosis over better parent, *sca* and *gca* effects and mean performance

Character	Crosses with high heterotic performance over better parent	Heterosis over better parent	*sca* effects	*gca* status		*Per se* performance
				Female	Male	
Seed yield/ plant (g)	CMS 234 A x RHA-95-C-1	104.01**	7.94**	L	L	70.89
	CMS 234 A x RHA-6D-1	86.06**	1.83	L	L	64.66
	CMS 234 A x RHA-271	85.15**	0.19	L	L	64.34
	CMS 234 A x R-64	82.22**	5.29	L	L	63.32
	CMS 234 A x R-298	80.49**	-2.85	L	L	64.18
	CMS 17 A x R-298	10.97**	2.47**	L	L	37.77
Oil content (%)	CMS 103 A x RHA-272	10.47**	1.96**	L	L	40.80
	CMS 4546 A x RHA-271	7.96**	0.19	L	L	39.33
	CMS 4546 A x RHA-272	7.69**	0.42	L	L	39.20
Hull content (%)	CMS 234 A x RHA-272	-20.73**	-4.55**	H	L	24.17
	CMS 234 A x R-64	-15.89**	-2.46**	H	H	25.65
	DCMS 51 A x R-298	-15.87**	-1.14**	H	H	25.54
	CMS 4546 A x RHA-271	-14.88**	-2.57**	H	H	25.70
Vol. wt (g/100 cc)	CMS 4546 A x R-298	14.96**	0.90	L	H	38.89
Per cent seed filling	CMS 234 A x RHA-95-C-1	30.68**	5.08	L	L	93.26
	CMS 234 A x R-64	21.79**	6.65*	L	L	91.13
	CMS 4546 A x RHA-95-C-1	20.97**	5.50*	L	L	92.94
	CMS 4546 A x RHA-6D-1	17.56**	1.21	L	H	90.32
No. of filled seeds/head	CMS 17 A x RHA-6D-1	101.74**	58.82*	H	L	496.98
	CMS 234 A x RHA-95-C-1	94.24**	56.46*	L	L	355.15
	CMS 17 A x R-298	82.40**	-5.86	H	H	449.34
	CMS 4546 A x RHA-272	78.08**	32.83	L	L	338.83
100 seed weight (g)	CMS 17 A x RHA-6D-1	29.79**	0.18	H	H	6.63
	CMS 17 A x RHA-95-C-1	22.75**	0.17	H	L	6.27
	CMS 17 A x RHA-272	22.00**	-0.07	H	L	6.23
	CMS 17 A x R-298	16.19**	-0.04	H	L	6.34
Days to maturity	CMS 103 A x RHA-271	-13.15**	-1.30	L	H	83.67
	CMS 103 A x R-298	-12.11**	-0.03	L	H	84.67
	DCMS 51 A x R-298	-11.97**	-3.42**	L	H	83.33
	CMS 103 A x RHA-272	-11.76**	-1.83	L	H	85.00
Head diameter (cm)	CMS 4546 A x RHA-272	28.23**	0.95*	L	L	15.94
	CMS 4546 A x RHA-271	23.83**	0.45	L	L	15.40
	CMS 234 A x RHA-271	22.54**	0.47	L	L	15.93
	CMS 234 A x RHA-272	21.67**	0.31	L	L	15.82
No. of leaves/er plant	CMS 234 A x RHA-271	32.01**	0.49	H	H	35.60
	CMS 234 A x RHA-95-C-1	31.55**	0.47	H	L	33.63
	CMS 17 A x RHA-271	30.34**	0.69	H	H	36.23
Plant height (cm)	CMS 234 A x RHA-95-C-1	50.70**	-2.22	L	H	216.70
	CMS 234 A x R-64	49.75**	2.54	L	H	217.33
	CMS 4546 A x RHA-95-C-1	42.78**	1.77	L	H	211.78
Days to flowering	CMS 103 A x R-298	-15.92**	0.68	L	H	56.33
	CMS 17 A x R-298	-15.27**	-0.66	L	H	57.33
	CMS 103 A x RHA-271	-14.93**	-0.86	L	H	57.00

On the other hand the crosses with significant *sca* also arose as a result of crosses between low x low or high x low general combiners. Considering hybrids with significant heterosis over better parent, combining ability and *per se* performance, five crosses CMS 234 A x RHA-95-C-1, CMS 234 A x RHA-6D-1, CMS 234 A x RHA-271, CMS 234 A x R-64 and CMS 234 A x R-298 exhibited significant heterosis over better parent. Further, it is noticed that all these hybrids had CMS 234 A as one of the parents in cross combinations. This suggests that CMS 234 A is a potential CMS line in realizing superior heterosis (104.0 %) for seed yield as seen from cross combination of CMS 234 A x RHA 95C-1. The prevalence of substantial magnitude of heterosis over better parent for seed yield has also been reported by Singh and Singh (2003) and Rajeswari *et al.* (2005). The hybrids CMS 17 A x R-298, CMS 103 A x RHA-272, CMS 4546 A x RHA-271 and CMS 4546 A x RHA-272 exhibited significant better parental heterosis for oil content (Nehru *et al.*, 2000). However, none of the hybrids expressed positive and significant heterosis for both seed yield and oil content. This suggests that there is a need to look for parents (A and R lines) with good *gca* for both yield and oil content and crosses produced from such parents have tendency to show correlated response. Nevertheless, manifestation of heterosis can mainly be attributed to the role of non-additive gene actions as seen from predominant proportion of SCA variance for the traits. As regards to heterosis for component traits, CMS 17 A in cross combination with RHA-6D-1 and RHA-95-C-1 has thrown out positive and significant heterosis for hull content, which involved parents mostly with high x high *gca* effects. Involving low x low general combiners in four crosses CMS 234A x RHA- 271, CMS 234A x RHA- 272, 4546 A x RHA-271 and 4546 A x RHA- 271 for head diameter and three crosses CMS 234A x RHA 95C-1, CMS 234A x R-64 and 4546 A x RHA 6D-1 for per cent seed filling resulted in positive and significant heterosis. The heterotic hybrids are also realized in respects of 100 seed weight, plant height and days to maturity as a result of crosses between L x H or H x L general combiners. Therefore, the pattern of *gca* of parents in cross combinations enables to predict heterosis during trait based improvements. The present investigation revealed the highest magnitude of heterosis for seed yield/plant followed by number of filled seeds/head and the least heterosis for oil content. The highest heterosis to the extent of 104% for seed yield over better parent in the cross CMS 234 A x RHA-95-C-1 is attributed to the contribution of heterosis from component characters such as hull content, per cent seed filling, number of filled seeds/head and earliness (Radhika *et al.*, 2001). From the present study it could be concluded that CMS 234 A, DCMS 51 A and CMS 17 A among the CMS lines and R-298 and RHA-6D-1 among the restorers are the potential parental lines for developing superior experimental hybrids.

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Inheritance studies in castor, *Ricinus communis* L.

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Abstract

In castor, *Ricinus communis* L. inheritance of anthocyanin pigment on stem (APS), bloom, capsule spinyness and cup shape of leaves is monogenic. Capsule spinyness is a co-dominant character and bloom is controlled by multiple alleles. Inheritance of papaya leaf lacination is digenic and shows dominant epistasis. Co-segregation studies revealed absence of linkage between the characters bloom, leaf shape, and APS.

Key words: Castor, inheritance, monogenic, multiple alleles, dominant epistasis and linkage

Introduction

Castor, *Ricinus communis* L. is an important oilseed crop of India, grown widely in the states of Gujarat and Andhra Pradesh. India is one of the centres of origin and large diversity can be seen in wild, semi-wild and cultivated forms. Extensive breeding efforts have resulted in release of some excellent varieties and hybrids. However, the genetics of the crop is poorly understood.

Though a large number of contrasting characters are available in castor, the knowledge about mode of inheritance and genetic linkage of characters is very scanty. In the present study, we attempted to understand inheritance of some morphological characters *viz.*, anthocyanin pigment on stem (APS), bloom on aerial plant parts, spinyness of capsules, cup shape of leaf and papaya leaf lacination. Co-segregation of the character pair's *viz.*, bloom-leaf shape, APS-bloom and APS-leaf shape was also studied.

Materials and methods

Plant material and crossing: Nine strains of castor were used to make six crosses. The source and distinct morphological characters of the parents are given in Table 1. The parental strains were crossed in the combinations: Kranthi x PCS-122, Jyoti x PCS-122, VP-1 x Kiran, Haritha x PCS-122, DPC-9 x Haritha and LRES-17 x PCS-137. A total of 1790 F_2 plants belonging to six crosses were studied for present investigation. Crossing and selfing is accomplished manually by hand crossing and bagging of spikes. The study was conducted at Regional Agricultural Research Station, Palem during 2002 to 2004.

Description of traits and observations

Anthocyanin pigment on stem (APS): Anthocyanin pigments are plant pigments called flavonoids, which are classified as secondary metabolites and are ubiquitous among flowering plants. The anthocyanin pigment imparts colours like pink, red, blue, and purple to the plants. In Castor strains can be distinguished based on expression of anthocyanin pigment and absence of pigment. Observations were recorded on 45 days old plants. Anthocyanin pigment in general is found in stem, petiole, and young leaves. An extreme purple morphotype expressing intense anthocyanin pigment in all aerial plant parts was also reported (Anjani, 2005).

Bloom: Castor plants have white waxy coating on aerial parts, which is generally referred as bloom. It imparts certain level of tolerance to sucking pests, whereas in the zero bloom (absence of bloom), plants are highly susceptible to jassids and triple bloom genotypes are more tolerant to drought compared to zero and single bloom. Four distinct classes are identified based on the presence/absence of bloom on different parts, *viz.*, triple (bloom on stem, petiole, lower and upper surface of leaf), double (on stem, petiole and lower surface of leaf), single (on stem only) and zero (absence of bloom). Observations are preferably taken in the early hours of the day, and to record bloom on upper surface of leaves, only young emerging leaves are observed.

Spinyness of capsules: Spinyness is a easily distinguishable morphological trait. Both types of capsules i.e., spiny and non-spiny are common in castor. Observations were recorded on developed capsules of the spike.

Leaf shape: The leaves of the strains VP-1 and LRES-17 have distinct cup shape, unlike the flat normal leaves. The 4th or 5th leaf from top is preferred for taking observations on leaf shape.

Leaf lacination: The strain PCS-122 has a distinct leaf lacination, popularly known as papaya leaf (deep lacination), which is distinguishable from normal (shallow) lacination. Similar to leaf shape, observations on leaf lancination were recorded on 4th or 5th leaf from top; young leaves were avoided.

The data collected were subjected to statistical analysis. Standard statistical procedures (Panse and Sukhatme, 1989) were used for fitting F_2 segregation ratios and

testing for goodness of fit using Chi-square test. Detection of linkage is done by calculating Chi-square due to linkage (2L) for 9:3:3:1 ratio (Mather, 1951).

Results and discussion

The dominance/recessive relation of the characters is revealed by F_1 phenotype (Table 2). The character APS present, flat shape of leaf, and normal lacination are dominant over their counterparts APS absent, cup shape of leaf, and papaya lacination, respectively. For bloom, triple is dominant over double and double is dominant over single and zero bloom. The F_1 phenotype for spiny nature of capsules is intermediate, i.e., sparsely spiny, indicating co-dominance nature of inheritance of these trait.

A total of 1790 plants belonging to six crosses were phenotyped to carry out inheritance and linkage studies. The F_2 segregation of the traits is given in Table 2. Segregation for APS is studied in 3 crosses *viz.*, Kranthi x PCS-122, Jyoti x PCS-122 and VP-1 x Kiran. The F_2 segregation in these crosses showed goodness of fit for 3 APS present: 1 APS absent ratio though the range of probability varied among the crosses. Pooled data of these crosses showed a segregation of 785 APS present: 257 APS absent, which has a goodness of fit (p=0.8-0.9) for 3:1 ratio. APS present of castor plants is found to be under the genetic control of at least one pair of alleles such that *A*-results in the production of anthocyanin pigment (red stem). The recessive genotype (*aa*) lacks this pigment and normal green colour is exhibited.

Inheritance of stem colour was reported to be monogenic by Solanki and Joshi (2001), which is in agreement with our findings. However, we observed differences in the intensity of the pigment among the F_2 segregants. The pigmentation ranged from specks of red colour anthocyanin to intense pigment. More over, the pigmented F_2 plants could not be grouped into discrete classes with naked eye based on extent of pigmentation.

In plants like Petunia (Quattrocchio *et al.*, 1993) and rice (Reddy, 1996) polygenes governing the production of anthocyanin pigment was reported, further its accumulation is been directly correlated to exposure to bright sunshine (Moshkin, 1986). Thus in Castor too, the observed variation for accumulation of anthocyanin may also be attributed to polygenes and environmental influence and complete absence of pigment in some genotypes may be hypothesised to be due to loss of function of a single upstream regulatory element governing the expression of anthocyanin.

Spinyness of capsules is found to be co-dominant trait; the F_1 plants showed intermediate phenotype i.e., sparsely spiny capsules. The F_2 segregation of the cross VP-1 x Kiran showed goodness of fit for 1 spiny: 2 sparsely spiny: 1 non-spiny (p=0.5-0.7). The recessive character is governed by single recessive gene, thus the recessive homozygotes *ss* are non-spiny; heterozygotes *Ss* produce sparsely spiny phenotype; and the dominant homozygotes *SS* results in spiny capsules. The inheritance of this character is in agreement with previous report. (Anjani, 1997). However, similar to the APS, large variation was observed in the expression of sparsely spiny character, nevertheless the trait can be distinguished from the spiny capsules without ambiguity. It was also observed that the capsules of the same spike also showed variation for sparsely spinyness. However, discrete classes could not be made for the observed variation. Thus it may be concluded that the expression of the alleles in heterozygotes is either influenced by environment or show variable expressivity.

The segregation data of two crosses *viz.*, VP-1 x Kiran and LRES-17 x PCS-137 indicates dominances of triple over double bloom and double bloom is governed by single recessive locus. The F_2 segregation studies on pooled data of the two crosses showed goodness of fit for 3:1 ratio (p=0.5-0.7). So also the individual F_2 segregation of the crosses VP-1 x Kiran and LRES-17 x PCS-137 showed good ness of fit for 3:1 ratio (p=0.1-0.2). Based on F_2 segregation data of 3 crosses *viz.*, Kranthi x PCS-122, Jyoti x PCS-122 and Haritha x PCS-122 it is concluded that single bloom is governed by single recessive locus. In all the 3 crosses the F_2 segregation showed a goodness of fit for 3:1 ratio and the same is true for pooled data over three crosses (p=0.7). The F_2 segregation of the cross DPC-9 x Haritha also showed goodness of fit for 3:1 ratio (p=0.5-0.7), which suggests that the recessive trait zero bloom is also governed by single locus.

Solanki and Joshi studied inheritance of bloom by taking presence of bloom and absence of bloom as two variants and concluded monogenic inheritance (Solanki and Joshi 2001). In our study, we attempted a detailed study by making crosses involving variants within presence of bloom *viz.*, single, double and triple. The results indicate that triple bloom is dominant over double bloom and both single and zero bloom are recessive to double bloom. Thus, we may hypothesise presence of at least four multiple alleles *viz.*, *b1*, *b2*, *b3* and *b4* belonging to single locus for the character bloom.

Flat leaf is found to be dominant over cup shape leaf, and cup shape leaf is governed by recessive allele of the locus. The F_2 segregation for this character is studied in 2 crosses *viz.*, VP-1 x Kiran and LRES-17 x PCS-137 and in both of them it showed a goodness of fit for 3:1 ratio (p=0.3-0.5). The pooled data also had a goodness of fit for 3:1 ratio (p=0.2).

Papaya leaf is recessive to normal leaf lacination and is governed by two loci. Digenic inheritance was confirmed by appearance of papaya leaf F_2 plants, which amount to 1/16 of total F_2 population. The F_1 phenotype is normal leaf lacination; while the F_2 plants expressed a third phenotype i.e., intermediate lacination in addition to parental types.

The character segregation is studied in two crosses *viz.*, Kranthi x PCS-122 and Jyoti x PCS-122 and in both the crosses F_2 segregation showed a goodness of fit to a ratio of 12 normal: 3 intermediate: 1 papaya (p=0.5-0.7 and 0.2-0.3, respectively), indicating dominant epistasis. The genotypes *A-B-* and *A-bb* produce normal leaf; *aaB-* produces intermediate leaf and *aabb* produces papaya leaf. The locus *A* is epistatic over B locus, thus producing normal phenotype irrespective of alleles at *B* locus.

We studied co-segregation of three-character pairs *viz.*, bloom - leaf shape, APS - bloom and APS - leaf shape (Table 3). The parents LRES-17 and VP-1 possess triple bloom and cup shaped leaves and their co-segregation was studied in two crosses *viz.*, LRES-17 x PCS-137 and VP-1 x Kiran. In both the crosses the calculated Chi-square was non-significant indicating independent assortment of the characters triple bloom and cup shape leaves with good ness of fit to 9:3:3:1 ratio.

In the crosses Kranthi x PCS-122 and Jyoti x PCS-122, co-segregation of the characters presence of APS and double bloom was studied. The Chi-square was non-significant indicating goodness of fit for 9:3:3:1 ratio, thus it is concluded that the characters APS present and double bloom also assort independently. Similar were the results from the cross VP-1 x Kiran for the characters APS absent and triple bloom, where in the 2L was also non-significant. Independent assortment of the characters APS absent and cup shaped leaves was confirmed based on the F_2 co-segregation data of the cross VP-1 x Kiran.

Thus, co-segregation studies observed no linkages for the characters under study. However, more studies on inheritance and linkage analysis are required, to understand genetics of Castor and the role of environment on the expression of characters.

Table 1 Morphological characteristics of castor genotypes

Genotype	Source	Stem colour	Bloom (waxy coating)	Spinyness of capsules	Leaf lacination	Leaf shape
Kranthi	RARS, Palem	Red	Double	Spiny	Normal	Flat
Haritha (PCS-124)	-do-	Green	Double	Spiny	Normal	Flat
Kiran (PCS-136)	*-do-*	*Red*	*Double*	*Non-Spiny*	*Normal*	*Flat*
PCS-122	-do-	Green	Single	Spiny	Papaya (deep)	Flat
PCS-137	-do-	Green	Double	Spiny	Normal	Flat
DCS-9 (Jyoti)	DOR	Red	Double	Spiny	Normal	Flat
DPC-9	-do-	Green	Zero	Spiny	Normal	Flat
LRES-17	-do-	Green	Triple	Spiny	Normal	Cup
VP-1	SDAU, Gujarat	Green	Triple	Spiny	Normal	Cup

RARS - Regional Agril. Research Station; DOR - Directorate of Oilseeds Research, Hyderabad; SDAU - Sardarkrushinagar Dandiwada Agril. University

Table 2 Segregation pattern in F_2 generation for various characters in castor

Morphological character	Cross	F_1 phenotype	No. of F_2 plants with designated phenotype			Ratio	$\chi 2$	Probability (%)
Red stem colour Vs Green	Stem colour		Red stem	Green stem	Total			
	Kranthi x PCS-122	Red stem	412	140	552	3:1	0.037	0.8-0.9
	Jyoti x PCS-122	Red stem	196	66	262	3:1	0.02	0.8-0.9
	VP-1 x Kiran	Red stem	177	51	228	3:1	0.841	0.3-0.5
Triple Vs double bloom	Bloom		Triple	double	Total			
	VP-1 x Kiran	Triple	161	67	228	3:1	2.33	0.1-0.2
	LRES-17 x PCS-137	Triple	74	17	91	3:1	2.09	0.1-0.2
Double Vs single bloom	Bloom		Double	Single	Total			
	Kranthi x PCS-122	Double	420	132	552	3:1	0.34	0.5-0.7
	Jyoti x PCS-122	Double	198	64	262	3:1	0.02	0.8-0.9
	Haritha x PCS-122	*Double*	*396*	*134*	*530*	*3:1*	*0.04*	*0.8-0.9*
Double Vs Zero bloom	Bloom		Double	Zero	Total			
	DPC-9 x Haritha	Double	97	30	127	3:1	0.167	0.5-0.7
Flat Vs Cup leaf	Leaf shape	Double	Flat	Cup	Total			
	VP-1 x Kiran	Double	166	62	228	3:1	0.584	0.3-0.5
	LRES-17 x PCS-137	Double	65	26	91	3:1	0.52	0.3-0.5
			No. of F_2 plants with designated phenotype					
Spiny Vs Non-spiny capsules	Capsule spinyness		Spiny	Sparsely spiny	Non- spiny	Total		
	VP-1 x Kiran	Sparsely spiny	61	116	51	228	1:2:1	0.94	0.5-0.7
Normal (shallow) Vs Papaya leaf (deep)	Leaf lacination		Normal	Very shallow	Deep (Papaya)			
	Kranthi x PCS-122	Normal	406	114	32	552	12:3:1	1.232	0.5-0.7
	Jyoti x PCS-122	Normal	199	53	10	262	12:3:1	2.59	0.2-0.3

Table 3 Joint segregation in F_2 generation of various characters in castor

Joint segregation of traits	Cross	No. of F_2 plants with designated phenotype					Ratio	χ^2L
Triple bloom – cup shape leaf		Triple bloom & flat leaf	Triple bloom & cup leaf	Double bloom & flat leaf	Double bloom & cup leaf	Total		
	LRES-17 X PCS-137	57	17	8	9	91	9:3:3:1	4.846
	VP-1 x Kiran	115	46	51	16	228	9:3:3:1	0.499
Red stem colour Double bloom		Red stem & double bloom	Red stem & single bloom	Green stem & double bloom	Green stem & single bloom			
	Kranthi X PCS-122	321	91	99	41	552	9:3:3:1	2.898
	Jyoti X PCS-122	150	46	48	18	262	9:3:3:1	0.381
Green stem Triple bloom		Red stem & triple bloom	Red stem & double bloom	Green stem & triple bloom	Green stem & double bloom			
	VP-1 x Kiran	129	48	32	19	228	9:3:3:1	1.754
Green stem Deep cup leaf		Red stem & flat leaf	Red stem & cup leaf	Green stem & flat leaf	Green stem & cup leaf			
	VP-1 x Kiran	126	51	40	11	228	9:3:3:1	1.122

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Heterosis for yield and yield attributing traits in castor, *Ricinus communis* L.

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Abstract

Heterobeltiosis and standard heterosis for seed yield and its attributes was studied in 40 hybrids developed through line x tester mating design (5 pistillate lines and 8 pollen parents) in castor. The significant positive heterosis over better parent (BH) and standard heterosis (SH) for seed yield ranged from -49.22% to 141.32% and -55.27% to 17.10%, respectively. The cross combinations ACP 1 x JI-35 (17.10) and JP 65 x VI-9 (13.82) exhibited significant positive standard heterosis over GCH 4 for seed yield/plant. These superior crosses also exhibited significant and positive heterosis for number of capsule/primary raceme, number of effective branches/plant and length of primary raceme. Hybrid vigour of superior crosses may be exploited commercially after verifying the stability performance across the environments over years.

Key words: Heterobeltiosis, standard heterosis, castor

Introduction

The exploitation of heterosis has been an important breeding tool in castor. With the availability of stable pistillate lines in castor, exploitation of heterosis on commercial scale has become feasible and economical (Gopani *et al.*, 1968). After release of first castor hybrid GCH-3, many high yielding hybrids have been released for commercial cultivation. Though per se performance of parental lines provides clues, reliable information on magnitude of heterosis and combining ability of parent for yield and its component characters involved in the inheritance in different characters are of 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 heterobeltiosis and standard heterosis in castor and to identify most heterotic hybrids.

Materials and methods

The experimental material comprised of five pistillate lines *viz.*, VP 1, Geeta, JP 65, SKP 4 and ACP 1 and 8 male parents *viz.*, I 21, EC 38538, JI 35, GC 2, EB 16, VI 9, SKI 283 and SPS 44-1. The parents were crossed in line x tester mating design and resulting 40 hybrids along with 13 parents and commercial hybrid GCH 4 were evaluated in Randomized Block Design with three replication during *kharif* 2007-08 at Regional Research Station, AAU, Anand. Each entry was planted in a single row of 10 dibbles keeping 90 cm row to row and 60 cm plant to plant distance. Recommended package of practices was followed for raising the normal crop. Observations on five randomly selected competitive plants were recorded for 9 traits (Table 1). However, days to 50% flowering and days to maturity were recorded on plot basis. Each character was analyzed separately using analysis of variance technique suggested by Panse and Sukhatme (1969) and heterosis was calculated in F_1 hybrids over better parent and standard check hybrid GCH 4.

Results and discussion

The analysis of variance for parents and their hybrids for different traits revealed significant differences for all the traits suggesting the presence of considerable genetic variation in respect of various traits studied. Parents vs. hybrids comparisons were significant for all the characters except for 100-seed weight (Table 1). This indicated presence of overall heterosis for all the characters studied.

Earliness in emergence of primary raceme is highly desirable traits for the crop like castor. Hence, the crosses exhibiting heterosis in negative direction are of immense value for earliness. Hybrid VP 1 x GC 2 exhibited significant and maximum negative heterobeltiosis (-23.50) and standard heterosis (-19.90) for days to 50% flowering. For early maturity VP 1 x EB 16 (-14.89) and SKP 4 x GC 2 (-12.57) depicted significant heterobeltiosis and standard heterosis in desirable direction, respectively. VP 1 x EC 38538 exhibited significant and desirable heterobeltiosis (-71.79) and standard heterosis (-57.66) for plant height and for the number of nodes upto primary raceme JP 65 x SKI 283 having high heterotic value in desirable direction for heterobeltiosis (-33.93) and standard heterosis (-21.86) over standard check hybrid GCH 4, respectively.

JP 65 x JI 35 showed significant and maximum positive heterosis over BP (58.74) and SH (43.94) for length of primary raceme. The crosses, VP 1 x SKI 283 and JP 65 x SPS 44-1 depicted significant and highest positive heterosis over BP (72.72) and SH (51.46), respectively for number of capsules on primary raceme. Maximum

heterosis was observed in hybrid ACP 1 x JI 35 over BP (137.30) as well as SH (9.71) for number of effective branches/plant. The crosses, ACP 1 x EB 16 and SKP 4 x I 21 depicted significant and highest positive heterosis over BP (18.14) and SH (21.52) respectively for 100 seed weight, whereas, cross ACP 1 x EC 38538 (9.94) depicted highest heterosis for oil content over SH.

Comparison of top five crosses for yield (ACP 1 x JI 35, ACP 1 x I-21, JP 65 x VI 9, JP 65 x EB-16 and Geeta X EB-16) based on *per se* performance, heterosis over BP and SH indicated that most superior hybrids were accompanied by significant and positive heterosis over BP and SH for yield attributes like length of primary raceme, number of capsules in primary raceme and number of effective branches/plant advocating that the high heterosis for seed yield resulted through contribution of its component traits (Table 2).

Table 1 Promising crosses for seed yield/plant with heterosis over standard check hybrid (GCH 4) and better parent (BP) in castor

Characters studied	Heterosis over	Range of heterosis		Best heterotic hybrids	No. of hybrids in desired direction
Days to 50% flowering	BP	-23.50	7.81	VP 1 x GC 2	29
	SH	-19.90	8.38	VP 1 x GC 2	21
Days to maturity of primary raceme	BP	-14.89	5.44	VP 1 x EB 16	33
	SH	-5.79	16.48	SKP 4 x GC 2	4
Plant height upto main raceme	BP	-71.79	85.45	VP 1 x EC 38538	21
	SH	-57.66	83.07	VP 1 x EC 38538	12
Nodes upto primary raceme	BP	-33.93	8.16	JP 65 x SKI 283	35
	SH	-21.86	28.83	JP 65 x SKI 283	16
Length of primary raceme	BP	-7.25	61.65	JP 65 x JI 35	27
	SH	-33.31	43.94	JP 65 x JI 35	10
No. of capsules on primary raceme	BP	-59.88	72.72	VP 1 x SKI 283	16
	SH	-57.50	51.46	JP 65 x SPS-44-1	11
No. of effective branches/plant	BP	-59.67	137.30	ACP 1 x JI-35	15
	SH	-73.59	9.71	ACP 1 x JI-35	4
No. of total branches/plant	BP	-55.43	108.77	JP 65 x VI-9	13
	SH	-58.31	16.35	ACP 1 x JI-35	7
100-seed weight	BP	-30.69	18.14	ACP 1 x EB 16	6
	SH	-13.22	21.52	SKP 4 x I 21	21
Oil content	BP	-9.41	12.40	JP 65 x EC 38538	10
	SH	-4.76	9.94	ACP 1 x EC 38538	12
Seed yield/plant (g)	BP	-49.22	141.32	JP 65 x VI-9	18
	SH	-55.27	17.10	ACP 1 x JI-35	2

BP = Better Parent SH = Standard Hybrid (GCH 4)

On the whole, considerable heterobeltiosis and standard heterosis observed for seed yield and other associated characters suggested the presence of large genetic diversity among the males and the females and also the unidirectional distribution of allelic constitution contributing towards desirable heterosis in the present material. Low magnitude of desirable heterosis and heterobeltiosis was observed for some of the characters *viz.*, oil content (%) and 100-seed weight (g) indicated the narrow genetic base among the males and the females and also the ambidirectional distribution of allelic constitution contributing towards undesirable heterosis or may be due to mutual cancellation of effects of dominant alleles present in the material. Similar finding were also reported in castor by Chakrabarty (1997); Joshi *et al.* (2001) and Lavanya and Chandramohan (2003).

Table 2 Heterobeltiosis and standard heterosis of superior crosses for seed yield and other components in castor

Crosses	Mean seed yield/ plant		Days To 50 % flowering	Days to maturity	Plant height (cm)	No of nodes/ plant	Length of primary raceme (cm)	No of capsule on primary spike	No of effective branches	Total no of branches	100 seed Weight (gm)	Oil content (%)	Seed yield/plant (gm)
ACP 1 x JI 35	241.38	BP	-10.38**	-9.57**	-8.39**	-14.37**	48.12**	-6.16	137.30**	68.71**	2.40	-0.59	32.43**
		SH	-0.52	-1.11	26.37**	2.53	21.73**	11.95**	9.71**	16.35**	0.61	-0.52	17.10*
ACP 1 x I-21	232.42	BP	-8.96**	-11.60**	-9.44**	-10.05**	41.74**	-8.58	27.70**	33.50**	-0.80	4.11**	27.51**
		SH	1.05	-1.56	24.92**	7.71*	16.98**	9.07	-3.82*	7.32**	15.06**	5.69**	12.79
JP 65 x VI 9	234.54	BP	-17.59**	-11.36**	1.85	-21.79**	23.33**	4.10	130.85**	108.77**	-11.27**	-6.00**	141.32**
		SH	-14.14**	-4.45*	-11.58**	-7.07*	20.54**	8.89**	6.05**	6.59**	-2.36	-2.69*	13.82*
JP 65 x EB 16	222.67	BP	-8.00**	-11.07**	22.48**	-3.57	37.34**	-1.67	120.28**	40.65**	8.10**	-9.41**	129.11**
		SH	-3.66	-1.56	30.23**	14.04**	17.92**	4.17*	1.19	7.32**	18.95**	-4.35**	8.06
Geeta X EB 16	218.16	BP	-6.00*	-1.57	-6.85	-11.31**	39.33**	-8.25	58.52**	50.06**	1.40	-6.18**	38.96**
		SH	-3.38	8.24**	-0.96	4.33	10.69**	-2.81	6.05**	13.91**	3.69	0.93	5.87
S.Ed.			3.19	6.11	5.16	0.94	2.89	3.39	0.74	0.76	0.88	0.53	13.13

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

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Studies on combining ability for seed yield and yield components in castor, *Ricinus communis* L.

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Abstract

Combining ability for 11 characters was studied using line x tester mating design involving 5 diverse pistillate lines and 8 inbred lines in castor. Combining ability analysis revealed that *gca* variances were significant for days to 50% flowering, plant height, number of nodes up to primary raceme and 100-seed weight, whereas, *sca* variances were significant for all the characters, reiterating the preponderance of non-additive gene action in the inheritance of these characters. The study also revealed that JP 65 and VP 1 among females while JI 35, I 21 and VI 9 among males were superior and consistent general combiners for seed yield and majority its yield contributing characters. VP 1, GC 2 and EB 16 were found to be good general combiners for days to 50% flowering, days to 50% maturity of primary raceme, plant height and number of nodes upto primary raceme. Good general combiners for oil content were VP 1 among females and SKI 283 amongst the males. The *per se* performance of crosses is not correlated with the sca effects of the crosses. The study also suggested the involvement of at least one good general combiner as parent result in better yielding cross. A parallel behavior was observed between *per se* performance and general combining ability effects of parents. The best three hybrids recorded maximum significant positive sca effects for seed yield were ACP 1 x SPS-44-1, VP 1 x GC 2 and SKP 4 x EC 38538.

Key words: Castor, *Ricinus communis* L., combining ability, *gca*, *sca*

Introduction

With the advancement in biometrical genetics, several techniques are now available which permit quantitative genetic analysis and selection of promising parents and cross combinations for its further exploitation. The parents which produce good progenies on crossing are of immense value to the plant breeder. Combining ability analysis is a powerful tool to discriminate good as well as poor combiners and choose appropriate parental material in breeding programmes. At the same time, it also gives the information about the nature of gene effects involved in the inheritance of various characters. Combining ability analysis was carried out in the present study to obtain information on selection of better parents and cross combinations for their further use in hybrid breeding programme.

Materials and methods

Five pistillate lines (Female) *viz.*, VP 1, Geeta, JP 65, SKP 4 and ACP 1 were crossed with 8 male pollen parents *viz.*, I 21, EC 38538, JI 35, GC 2, EB 16, VI 9, SKI 283 and SPS 44-1 in a line x tester mating design to obtain 40 hybrids during *kharif* 2006-07. The hybrids (F_1) along with their parents were grown in a Randomized Block Design with three replications during *kharif* 2007-08 at Regional Research Station, Anand Agricultural University, Anand. Each entry was planted in a single row of 10 dibbles keeping row to row 90 cm and plant to plant 60 cm distance. Recommended package of practices was followed for raising the normal crop. Observations on five randomly selected competitive plants were recorded for 9 traits (Table 1). The mean values of these traits were subjected to combining ability analysis as per methods suggested by Kempthorne (1957).

Results and discussion

Variance estimates due to gca (average) were significant for days to 50% flowering, plant height, number of nodes up to primary raceme and 100-seed weight indicating that additive gene action may play important role for these characters. While for the rest of the traits it was not significant indicating that additive gene action may not be playing much role and presence of non-additive gene action in the expression of these characters (Table 1). Variance estimates due to *sca* (average) were highly significant for all the characters. Significant estimates of $\sigma^2 sca$ for all the characters suggested the involvement of non-additive gene action for the inheritance of all the traits studied.

Significant estimates of $\sigma^2 gca$ for the characters mentioned above and the highly significant estimates of $\sigma^2 sca$ for all the characters emphasized the importance of additive as well as non-additive gene actions. These results are akin to the reports of Gondaliya *et al.* (2001), Tank *et al.* (2003) and Solanki *et al.* (2004). However, from the $\sigma^2 A/\sigma^2 D$ ratio, preponderance of non-additive gene

action was evident for all the characters, except for plant height and 100-seed weight. These results are in conformity with the reports of Ramu *et al.* (2002) and Lavanya and Chandramohan (2003).

The results of GCA effects (Table 2) revealed that none of the parent was found to be good general combiner for all the traits. However, an overall appraisal of general combining ability effects revealed that JP 65 and VP 1 were found to be a good and consistent general combiner for majority of the traits. Among males, good and consistent general combining ability effect was exhibited by the parents JI 35 and I 21 and VI 9.

Table 1 Analysis of variance and variance estimates for combining ability for seed and its yield in castor

Source	df	Days to 50 % flowering	Days to maturity	Plant height (cm)	No of nodes/ plant	Length of primary raceme	No of capsule on primary raceme	No of effective branches	No of total branches	100 seed weight (gm)	Seed yield/plant (gm)	Oil content (%)
Replication	2	3.68	52.11	174.37 **	1.61 *	209.33 **	120.85 **	4.20 **	2.69	3.33	1279.73 **	0.23
Hybrid	39	63.56 **	184.26 **	951.13 **	8.92 **	257.82 **	737.07 **	55.79 **	57.38 **	25.91 **	3290.63 **	10.81 **
Females	4	175.84 **	300.88	1792.99 *	32.58 *	257.81	876.74	68.96	68.92	18.59	5471.29	22.41 *
Males	7	83.29	233.05	2653.64 **	5.85	490.06 *	1290.92	113.38 *	114.94 *	76.62 **	6018.48 *	14.62
F x M	28	42.59 **	155.40 **	405.24 **	6.31 **	199.75 **	578.66 **	39.52 **	41.34 **	14.28 **	2297.15 **	8.20 **
Error	78	4.36	17.43	10.10	0.31	14.35	17.05	0.75	0.94	1.13	244.80	0.34
σ^2F		7.17	11.95	74.29	1.34	10.22	35.81	2.84	2.84	0.73	217.20	0.92
σ^2 M		5.29	14.59	176.24	0.37	31.83	84.91	7.50	7.61	5.03	384.01	0.95
σ^2 *gca*		6.45	12.97	113.50	0.97	18.53	54.70	4.63	4.67	2.38	281.36	0.93
σ^2 *sca*		12.91	47.09	131.72	1.99	62.40	187.14	12.90	13.50	4.37	679.57	2.59
σ^2A		12.89	25.93	227.00	1.94	37.06	109.39	9.27	9.34	4.76	562.71	1.86
σ^2D		*12.91*	*47.09*	*131.72*	*1.99*	*62.40*	*187.14*	*12.90*	*13.50*	*4.37*	*679.57*	*2.59*
σ^2A/σ^2D		0.99	0.55	1.72	0.97	0.59	0.59	0.72	0.69	1.09	0.83	0.72
Degree of dominance		*1.00*	*1.35*	*0.76*	*1.01*	*1.30*	*1.31*	*1.18*	*1.20*	*0.96*	*1.10*	*1.18*

Table 2 Estimates of general combining ability (*gca*) effects for yield and its components

Parents / hybrids	Days to 50 % flowering	Days to maturity	Plant height (cm)	No of nodes/plant	Length of primary raceme	No of capsules on primary raceme	No of effective branches	total no of branches	100 seed weight (gm)	Seed yield/plant (gm)	Oil content (%)
					Female parents						
VP 1	-3.87 **	-1.58 **	-8.72 **	-1.53 **	0.08	-7.76 **	0.70 **	0.61 **	-0.70 **	-14.85 **	1.15 **
Geeta	1.84 **	6.05 *	14.12 **	1.56 **	-0.56 **	3.07 **	2.63 **	2.55 **	-1.00 **	6.32	-0.42 **
JP 65	-0.91 **	-2.66 **	0.12	-0.65 **	5.22 **	7.99 **	-0.60 **	-0.19 **	0.48 **	20.01**	-0.96 **
SKP 4	-0.24 **	-1.99 **	-0.75 **	0.43 **	-3.81 **	-3.56 **	-1.45 **	-1.74 **	1.17 **	3.88	-0.69 **
ACP 1	3.18 **	0.18	-4.77 **	0.19 **	-0.93 **	0.26	-1.27 **	-1.24 **	0.04	-15.36 **	0.92 **
SEd±	0.40	0.77	0.65	0.12	0.72	0.85	0.18	0.19	0.22	3.28	0.13
CD (P=0 05)	0.80	1.53	1.29	0.24	1.44	1.69	0.37	0.38	0.44	6.53	0.13
					Male parents						
I-21	1.06 *	-0.24**	12.34 **	1.01 **	3.49 **	-3.26 **	0.92 **	1.29 **	3.22 **	19.91**	0.12 *
EC-38538	2.33 **	7 09 **	-23 82 **	-0.30 **	-7.71 **	-8.55 **	-4 33 **	-4.53 **	0.68 **	-36.29 **	0.74 **
JI-35	0.46	-2.78 **	19 98 **	0.70 **	10 05 **	12 92 **	3.19 **	3.07 **	-1.06 **	25.45**	-1.53 **
GC-2	-4.54 **	-5.78 **	-1.23 **	-0.70 **	2.19 *	-6.04 **	-0.51 **	-0.65 **	-3.07 **	-15.49 **	-0.09 **
EB-16	-0.14 **	-0.44 **	-7.00 **	-0.24 **	-6.91 **	11.90 **	2.10 **	1.97 **	1.44 **	7 72	-1.25 **
VI-9	-1.41 **	-2.51 **	-4.80 **	-0.50 **	-1.65 **	-0.12 **	1.83 **	1.98 **	-3.04 **	4.54	-0.16 **
SKI-283	2.99 **	2.16	-1.96 **	-0.41 **	-0.36 **	4.57 *	-3.84 **	-3.67 **	1.77 **	4.53	1.15 **
SPS-44-1	-0.74 **	2.49	6.49 **	0.45 **	0.90	12.37 **	0.64 **	0.53 **	0.08	-10.37 **	1.00 **
SEd±	0.51	0.97	0.82	0.15	0.92	1.07	0.23	0.24	0.29	4.15	0.17
CD (P=0.05)	1.01	1.93	1.63	0.30	1.82	2.13	0.46	0.48	0.55	8.26	0 34

It was also observed that the per se performance for different characters in general agreement with the *gca* effects. However, this can not be taken as a rule because parents or genotypes with high *per se* performance need not always be good general combiners e.g. VP 1, JP 65 and JI 35 was good general combiner for seed yield/plant but these parents were found poor on the basis of *per se* performance. This could be attributed due to the intra and/or inter-allelic interaction of genes concerned with the character modified by environmental factors.

The perusal of data (Table 3) revealed that only few hybrids exhibited significant and desirable *sca* effects for 1 or 2 traits. Majority of the crosses with significant sca effects involved at least one good combiner parent indicating the significance of non-additive gene action.

Table 3 Estimates of specific combining ability (sca) effects for yield and its components

Hybrid No.	Hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of nodes/ plant	Length of primary raceme	No. of capsules on primary spike	No. of effective branches	No. of total branches	100 seed weight (g)	Seed yield/ plant (g)	Oil content (%)
H1	VP1 x I-21	1.73	-5.09*	2.14	-0.73*	-1.11	-6.32*	-1.89**	-1.44**	-1.48*	-12.95	-1.67**
H2	VP1 x EC-38538	2.47*	1.24	-7.04**	-0.68*	0.43	-8.06**	-0.51	-0.15	3.10**	-7.49	-0.44
H3	VP1 x JI-35	4.67**	10.11**	-15.51**	0.26	12.13**	-15.79**	1.77**	2.12**	-0.63	11.28	-0.87*
H4	VP1 x GC-2	-1.67	2.78	17.77**	-0.30	8.60**	17.89**	0.66	0.56	1.94**	46.62**	0.34
H5	VP1 x EB-16	-4.73**	-9.23**	1.74	-0.96**	3.16	3.16	4.80**	3.94**	-2.34**	-1.97	-0.20
H6	VP1 x VI-9	2.87**	4.51*	5.34**	0.72*	0.63	1.31	-3.27**	-3.93**	-2.59**	0.17	0.96*
H7	VP1 x SKI-283	-1.20	-0.16	1.70	0.81*	7.47**	21.29**	1.80**	1.99**	-3.09**	17.84	0.50
H8	VP1 x SPS-44-1	-4.13**	-4.16	-6.15**	0.89**	-7.04**	-13.47**	-3.35**	-3.08**	5.09**	-53.49**	1.35**
H9	Geeta x I-21	3.03**	6.95**	0.70	2.23**	0.20	-2.22	0.24	-0.12	0.86	-1.33	-0.20
H10	Geeta x EC-38538	3.43**	-4.72*	10.58**	-1.26**	-1.87	-4.96*	-2.24**	-2.09**	-1.43*	-33.06**	1.28**
H11	Geeta x JI-35	-1.71	-7.18**	13.85**	0.93**	3.30	13.04**	-2.23**	-2.43**	-0.62	-4.21	-0.25
H12	Geeta x GC-2	-0.71	-6.18**	-4.80*	0.93**	0.30	-8.74**	1.66**	1.49**	-1.42*	9.61	0.16
H13	Geeta x EB-16	-0.12	4.15	11.43**	-0.39	-6.55**	7.40**	2.13**	2.43**	-1.26*	23.74*	1.02**
H14	Geeta x VI-9	-1.52	8.88**	14.36**	-0.93**	-6.67**	-7.49**	-0.20	-0.27	1.38*	-27.15**	0.33
H15	Geeta x SKI-283	1.76	4.22	14.14**	-0.74*	-2.70	-9.51**	-3.20**	-2.75**	0.89	14.53	-1.43**
H16	Geeta x SPS-44-1	-4.18**	-6.12**	19.61**	-0.78*	13.99**	12.46**	3.85**	3.74**	1.60*	17.87	-0.88*
H17	JP 65 x I-21	-1.56	2.33	-5.96**	-0.93**	-6.78**	6.77**	-0.06	0.28	0.41	-14.50	0.29
H18	JP 65 x EC-38538	-3.16**	-4.68*	-8.68**	-1.90**	-13.25**	-11.97**	-2.28**	-2.36**	-3.25**	32.16**	-2.23**
H19	JP 65 x JI-35	-2.96*	0.86	0.39	-0.46	10.46**	0.49	-3.93**	-3.82**	1.32*	-20.65*	1.24**
H20	JP 65 x GC-2	3.04**	5.19*	-3.53	0.48	-2.55	11.11**	-1.50**	-1.51**	-0.50	-0.91	-1.25**
H21	JP 65 x EB-16	1.31	-1.81	21.97**	3.36**	12.81**	10.91**	1.76**	2.14**	2.22**	8.73	-0.09
H22	JP 65 x VI-9	-4.09**	-4.08	-6.22**	0.21	9.02**	-18.34**	2.83**	3.93**	-0.24	12.61	-0.38
H23	JP 65 x SKI-283	2.51*	-1.74	-7.40**	-2.15**	-11.87**	-20.09**	-2.30**	-3.02**	2.40**	-20.77*	2.21**
H24	JP 65 x SPS-44-1	4.91**	3.93	10.42**	1.39**	2.15	21.11**	5.48**	4.91**	-2.36**	3.32	0.21
H25	SKP 4 x I-21	-2.23	0.66	-1.10	-0.84*	-0.35	-9.69**	-3.15**	-4.18**	0.59	-2.87	0.07
H26	SKP 4 x EC-38538	-4.16**	-6.66**	7.46**	2.27**	11.65**	19.84**	3.51**	3.90**	-0.01	33.66**	-1.55**
H27	SKP 4 x JI-35	1.38	-2.14	3.79*	-0.51	-5.77**	6.67**	1.12*	1.07*	0.74	-14.92	-0.28
H28	SKP 4 x GC-2	-0.63	-3.48	-4.40*	-0.67*	-1.08	-6.31*	-0.25	-0.68	-0.19	-28.88**	-0.82*
H29	SKP 4 x EB-16	2.64*	6.86**	-8.16**	-0.12	-6.92**	-16.49**	-5.45**	-5.17**	-0.77	0.22	0.44
H30	SKP 4 x VI-9	-1.43	-2.74	4.38*	-0.99**	4.45*	8.44**	5.08**	4.96**	1.91**	12.30	-0.65
H31	SKP 4 x SKI-283	-4.49**	-7.41**	16.47**	2.21**	4.36*	7.52**	4.75**	5.14**	1.12	17.62	-0.81*
H32	SKP 4 x SPS-44-1	8.91**	14.93**	-18.45**	-1.35**	-6.35**	-9.98**	-5.60**	-5.06**	-3.38**	-17.13	3.59**
H33	ACP 1 x I-21	-0.98	-4.84*	4.23*	0.27	8.04**	11.50**	4.87**	6.00**	-0.38	31.64**	1.51**
H34	ACP 1 x EC-38538	1.43	14.83**	-2.32	1.57**	3.04	5.15*	1.52**	0.70	1.59*	-25.27**	2.94**
H35	ACP 1 x JI-35	-1.38	-1.64	-2.52	-0.21	4.14*	-4.41	3.27**	3.06**	-0.80	28.50**	0.16
H36	ACP 1 x GC-2	-0.04	1.69	-5.04**	-0.44	-5.26*	-13.96**	-0.57	0.14	0.17	-26.44**	1.57**
H37	ACP 1 x EB-16	0.89	0.03	-4.14*	-1.89**	-2.50	-4.99*	-3.24**	-3.35**	2.16**	-30.72**	-1.17**
H38	ACP 1 x VI-9	4.16**	-6.58**	10.87**	0.99**	-7.43**	16.09**	-4.44**	-4.69**	-0.46	2.07	-0.26
H39	ACP 1 x SKI-283	1.43	5.09*	4.36*	-0.13	2.74	0.80	-1.04	-1.37*	-1.32*	-29.22**	-0.47
H40	ACP 1 x SPS-44-1	-5.51**	8.58**	-5.43**	-0.17	-2.76	-10.13**	-0.38	-0.51	-0.95	49.43**	-4.27**
	SEd	1.14	2.17	1.83	0.34	2.05	2.40	0.52	0.53	0.62	9.28	0.38
	CD (P=0.05)	2.26	4.32	3.65	0.67	4.07	4.77	1.04	1.06	1.24	18.48	0.75

The estimates of sca effects revealed that none of the hybrids was consistently superior for all the traits. The best three hybrids on the basis of significant positive *sca* effects for seed yield/plant were ACP 1 x SPS 44-1, VP 1 x GC 2 and SKP 4 x EC 38538. It also depicted positive *sca* effects for majority of its yield attributing traits.

A perusal of data showed a good agreement between best general combining parents and best performing parents for *most of the traits. This suggested that while selecting the* parents for hybridization programme, *per se* performance of parents should be given due consideration. Such parallel behavior of *per se* performance and general combining ability was also reported by Dangaria *et al.* (1987); Pathak et al. (1989); Lavanya and Chandramohan (2003) and Thakker *et al.* (2005). The best three hybrids with maximum significant positive *sca* effects for seed yield/plant *viz.*, ACP 1 x JI35 (poor x good), JP 65 x VI 9 (good x average) and JP 65 x EB 16 (good x average) had also significant desired heterotic response over betters parent and standard check hybrid. High yielding hybrids had high *sca* effects and high heterosis for most of its yield contributing characters. This appeared appropriate as yield being a complex character depends on a number of its component traits.

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Combining ability studies for certain quantitative characters in linseed, *Linum usitatissium* L.*

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Abstract

Combining ability for 10 characters was studied using 7 lines *viz.*, BAU-610A, EC-384154 JRF-3, JRF-4, Polf-34, H-25 and H-22 as females and 4 testers Padmini, Parvati, Shubhra and LCK-3003 as male crossed in line x tester mating design. Analysis of combining ability revealed the existence of highly significant variation among crosses for all characters in F_1 and F_2 generations, respectively. The lines BAU-610A was found to be good general combiner for days to maturity, plant height, number of primary branches/plant, 1000-seeds weight, seed yield/plant, oil content, days to 50% flowering and incidence of *Alternaria* blight in F_1 generation. However, BAU-610A had significantly positive *gca* effects for days to 50% flowering and incidence of *Alternaria* blight and poor general combiner in seed yield/plant and oil content in F_2 generations. The variance due to line x tester were significant for all the characters, suggesting the presence of non-additive gene effect for these traits. The crosses BAU 610-A x Shubhra, JRF-3x Padmini, JRF-4xPadmini in F_1 generation and EC-384154 x Shubhra, JRF-3 x Parvati in F_2 generation were the most promising for improvement of seed yield and one or more of its component traits.

Key words: Line x tester, *gca*, *sca*, linseed

Introduction

In any breeding programme the appropriate selection of parents based on their combining ability not only provides necessary information regarding the choice of parents but also simultaneously illustrate the nature and magnitude of gene action involved. The line x tester mating design helps in realising the objective to estimate the combining ability of parents and by there selecting superior parents as well as cross combinations. Accordingly, the present investigation was undertaken to have the knowledge about the yield and other yield attributing characters of nature of combining ability for some newly developed male and female lines of linseed. *Linum usitatissium* L. and gene action for yield and other yield attributing characters.

Materials and methods

The experimental materials used in present investigation consisted of 28 crosses derived through line x tester design were grown during *rabi* 2004-05 for advancement of generation and promising 14 F.s were back crossed to their respective parents for inheritance studies and selfed F_2 seeds were also harvested. The experiment comprising of 67 genotypes (28 F_1s + 28 F_2s + 11 parents) was conducted in a Randomized Block Design with three replications during *rabi* 2005-06 at Oilseeds Research Farm, Kalyanpur of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. These entries were sown in single row of 3m with 30 cm row to row and 5 cm plant to plant spacing. The observations were recorded on 10 characters (Table 1).

Components of variance estimates of phenotypic and genotypic coefficient of variation (PCV and GCV) were evaluated as per Burton (1952). Heritability in the broad sense was calculated following Hanson (1963) and expected genetic advance was estimated as per Johnson *et al.* (1955) and Kempthorne (1957).

Results and discussion

The variances among the lines in respect of their general combining ability were highly significant for all of the characters in F_1 and F_2 generations (Table 1). The differences among the testers arising primarily due to their *gca* were highly significant for the characters in F_1 and F_2 except days to maturity, number of seeds/capsule, 1000-seeds weight and incidence of *Alternaria* blight in F_2. The variances among the crosses due to line x tester interaction component indicating their *sca*, were highly significant for all the characters in F_1 and F_2 except number of seeds/capsule and 1000-seeds weight in F_2 and incidence of *Alternaria* blight in both generations.

Estimates of *gca* effects showed that it was not possible to pick up a good general combiner for all characters because the combining ability effects of parents were not consistent for all the yield components. The lines BAU-610A was found to be good general combiner for days to maturity, plant height, number of primary branches/plant, number of capsules/plant, 1000-seeds weight, seed yield/plant and oil content days to 50%

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flowering and least incidence of *Alternaria* blight in F_1 generation. However, BAU 610A had significantly positive *gca* effects for days to 50% flowering and incidence of *Alternaria* blight and poor general combiner in seed yield/plant and oil content in F_2 generation. JRF-4 was found to be a good general combiner for plant height, oil content and more incidence of *Alternaria* blight in both F_1 and F_2 generations. H-25 and H-22 were identified as poor general combiner for days to 50% flowering and number of capsules/plant in F_1 and F_2 generations. The lines EC-384154 was a good general combiner for days to 50% flowering and days to maturity in respect of late maturity duration in both F_1 and F_2 generations. Among the testers Parvati proved to be a good general combiner for delayed maturity and tallness in both F_1 and F_2 generations whereas, Padmini was best general combiner for earliness and dwarfness, seed yield, oil content and least incidence of *Alternaria* blight in F_1 generation. Shubhra was identified as average general combiner for days to 50% flowering and number of primary branches/plant and number of capsules/plant in both F_1 and F_2 generations. H-22 was adjudged to be good general combiner for least incidence of *Alternaria* blight whereas, JRF-3 and LCK-3003 for seed yield/plant in both F_1 and F_2 generations.

In the present investigation, the crosses exhibiting higher estimates of desirable *sca* effects common in both the generations were BAU 610A x Parvati for days to 50% flowering and EC-384154 x Padmini for number of capsules/plant. These common crosses over the generations indicate additive x additive type of gene action for the expression of concerned traits.

The cross combinations H-25 x Parvati, BAU 610A x Padmini, H-25 x Shubhra and EC-384154 x Parvati, Polf-34 x Padmini, JRF-4 x LCK-3003 for days to maturity; JRF-4 x Parvati, EC-384154 x Parvati, BAU 610A x LCK-3003 and Polf-34 x Parvati, H-25 x Parvati, H-22 x LCK-3003 for plant height; Polf 34 x Parvati, JRF-4 x Padmini, BAU 610A x LCK-3003 and EC-384154 x Padmini for number of primary branches/plant; H-25 x LCK-3003, EC 384154 x Padmini, BAU-610A x LCK-3003 and JRF-4 x Parvati, EC384154 x Padmini, EC-384154 x Shubhra for capsules/plant; H-25 x Parvati, BAU 610A x Shubhra, JRF-4 x Shubhra and H-22 x LCK-3003 for number of seeds/capsules; BAU 610A x Shubhra, JRF-3 x Padmini, H-22 x Parvati and EC384154 x Shubhra for 1000-seeds weight; BAU 610A x Shubhra, JRF-3 x Padmini, JRF-4 x Padmini and EC-384154 x Shubhra, JRF-3 x Parvati, H-25 x Parvati for seed yield/plant; Polf-34 x Parvati, H-22 x LCK-3003, BAU 610 A x Shubhra and EC-384154 x Padmini, JRF-3 x Parvati, Polf-34 x LCK-3003 for oil content; JRF4 x Shubhra, Polf-34 x LCK-3003, EC-384154 x Padmini and H-22 x Padmini, EC-384154 x Parvati, EC-384154 x Shubhra for incidence of *Alternaria* blight were the good specific combinations for F_1 and F_2 generations, respectively.

In general, maximum crosses showing significant *sca* effects, were invariably associated with better *per se* performance for respective traits (Table 3). The results are in agreement with Patil and Chopda (1983) who concluded that mean performance of the crosses were closely associated with *sca* effects and hence, selection of crosses on the basis of heterotic response should prove effective.

The good specific combiners for different characters involved parents with low x low, low x average, average x average, average x high and high x high general combinations but may also occur in other types of parent combinations. However, in majority of the cases the crosses exhibiting high *sca* effects were found to have both or one of the parents as good general combiners for the characters under reference. Kushalkar *et al.* (2002), Tewari *et al.* (2004) and Ratanparkhi *et al.* (2005) also observed that most cross combinations with high *sca* effects involved at least one high general combining parent. Most interesting crosses are those that involve both parents with high *gca* and posses high *sca* effects. The major parts of such variance would be fixable in later generations.

Table 1 Analysis of variance for combining ability for 10 characters in linseed (mean square)

Sources of variation	d.f.	Gen.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of Primary branches/ plant	No. of capsules/ plant	No. of seeds/ capsule	1000-seeds weight (g)	Seed yield/ plant (g)	Oil content (%)	Incidence of *A.blight* (0-5 scale)
Females (Lines)	6	F_1	35.05**	130.14**	231.99**	2.29**	273.15**	0.46**	2.79**	8.56**	3.90**	2.70**
	6	F_2	235.21**	113.33**	216.72**	7.76**	260.21**	1.26**	0.37**	8.75**	7.01**	2.14**
Males (Testers)	3	F_1	39.88**	55.65**	1150.73**	0.91**	109.70**	2.17**	2.15**	5.23**	2.56**	1.65*
	3	F_2	194.91**	6.62	2746.67**	0.78**	42.77**	0.46	0.27	7.20**	2.43**	0.33
Female x male	27	F_1	14.38**	68.96**	247.39**	1.47**	143.05**	1.18**	2.16**	5.98**	2.84**	1.61*
	27	F_2	25.21**	24.30**	217.45**	0.67**	111.22**	0.67*	0.28	4.76**	2.14**	0.31
Error	76	F_1	3.20	5.33	3.15	0.21	21.42	0.12	0.24	0.44	0.18	0.36
	76	F_2	5.08	5.48	4.24	0.27	9.49	0.37	0.16	0.19	0.13	0.06

* Significant at 5% probability level, ** Significant at 1% probability level

Table 2 Estimates of general combining ability effects for 10 characters in linseed

F_1 Generations

Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of Primary branches/ plant	No. of capsules/ plant	No. of seeds/ capsule	1000-seeds weight (g)	Seed yield/plant (g)	Oil content (%)	Incidence of *A.blight* (0-5 scale)
Lines										
BAU-610 A	-1.89**	-2.15**	1.68**	0.35*	8.10**	0.11	0.39**	1.06**	0.40**	-0.57**
EC-384154	1.52**	4.18**	-5.46**	0.01	-0.14	0.11	0.12	0.71**	0.04	-0.02
JRF-3	-0.06	-2.32**	0.50	-0.57**	4.18**	0.11	0.59**	0.43*	0.54**	0.03
JRF-4	1.02*	0-0.82	3.12**	0.10	-4.49**	0.19	-0.17	-0.12	0.42**	0.88**
Polf-34	2.44**	5.118**	7.05**	0.60**	0.51	-0.06	0.28*	0.06	0.08	-0.13
H-25	-1.56**	-2.99**	-3.35**	-0.57**	-2.99*	0.06	-0.48**	-0.79**	-1.06**	0.23
H-22	-1.48**	-1.07	-3.54**	4.10**	-4.90**	-0.39**	-0.73**	-1.35**	-0.43**	-0.42*
SE (sgi) ±	0.52	0.67	0.51	0.13	1.34	0.10	0.14	0.19	0.12	0.17
SE (sgi) ± sgj	0.73	0.94	0.72	0.19	1.89	0.14	0.20	0.27	0.17	0.25
Testers										
Padmini	-1.63**	0.89	-4.78**	0.12	-0.63	0.07	0.10	0.41**	0.49**	-0.36**
Parvati	1.70**	-1.39**	10.87**	0.12	-2.77**	0.07	0.40**	-0.16	-0.10	+0.19*
Shubhra	0.23	-1.35**	-1.51**	0.07	0.75	-0.45**	-0.34**	-0.64**	-0.33**	0.06*
LCK-3003	-0.30	1.85**	-4.59**	-0.31**	2.65*	0.39**	-0.15	0.39**	-0.07	-0.89
SE (sgi) ±	0.39	0.50	0.30	0.10	1.01	0.08	0.11	0.14	0.09	0.13
SE (sgi) ± sgj	0.55	0.71	0.55	0.14	1.43	0.11	0.15	0.20	0.13	0.19

F_2 Generations

Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of Primary branches/ plant	No. of capsules/ plant	No. of seeds/ capsule	1000-seeds weight (g)	Seed yield/plant(g)	Oil content (%)	Incidence of *A.blight* (0-5 scale)
Lines										
BAU-610 A	3.07**	0.40	-1.17*	0.43**	0.76	-0.26	0.00	-0.35**	-0.95**	0.26**
EC-384154	5.49**	2.07**	1.09	-0.65**	0.18	-0.26	0.11	-1.29**	-0.37**	0.55**
JRF-3	4.40**	4.74**	-5.33**	-1.07**	-4.24**	-0.01	0.27*	0.96**	0.52**	0.22**
JRF-4	-0.01	-1.93**	4.72**	-0.15	8.93**	-0.18	0.01	-0.85**	0.38**	0.17*
Polf-34	-5.51**	-5.10**	-5.05**	1.43**	1.76*	0.57**	-0.01	0.84**	1.09**	-0.19*
H-25	-3.18**	-0.26	5.44**	-0.15	-4.57**	0.32	-0.12	0.23	0.24*	-0.69**
H-22	-4.26**	0.07	0.30	0.18	-2.82**	-0.18	0.27*	0.45**	-0.91**	-0.33**
SE (sgi) ±	0.65	0.68	0.59	0.15	0.89	0.18	0.12	0.13	0.10	0.07
SE (sgi) ± sgj	0.92	0.96	0.84	0.21	1.26	0.25	0.16	0.18	0.15	0.10
Testers										
Padmini	-4.25**	-0.05	-9.63**	-0.12	-2.10**	0.01	0.15	-0.24*	0.37**	0.04
Parvati	2.04**	-0.38	16.58**	-0.17	0.98	0.20	-0.07	-0.79**	-0.13	0.14*
Shubhra	-0.15	-0.38	-4.07**	0.02	0.29	-0.08	0.03	0.56**	-0.41**	-0.01
LCK-3003	2.34**	0.81	-2.88**	0.26*	0.90	-0.13	-0.11	0.39**	0.16*	-0.16**
SE (sgi) ±	0.49	0.51	0.45	0.11	0.67	0.13	0.09	0.10	0.08	0.06
SE (sgi) ± sgj	0.70	0.72	0.64	0.16	0.95	0.19	0.12	0.13	0.11	0.08

* Significant at 5% probability level, ** Significant at 1% probability level

Table 3 Best specific combinations along with *sca* performance and *gca* effects of the parents for different characters in linseed

Characters	Best specific combinations	F_1 *per se* performance	*Gca* effects of the parents	Best specific combinations	F_2 *per se* performance	*Gca* effects of the parents
Days to 50% flowering	JRF-4xPadmini	-4.45**	HxL	JRF-4xLCK-3003	-3.70	AxH
	H-22xLCK-3003	-2.29*	LxA	EC-384154xParvati	-3.54	HxH
	BAU-610AxParvati	-2.20	LxH	BAU-610AxParvati	-2.79*	HxH
Days to maturity	H-25xParvati	-7.77**	LxL	EC-384154xParvati	-5.12**	HxA
	BAU-610xPadmini	-5.56**	HxA	Polf-34xPadmini	-3.29*	HxA
	H-25xShubhra	-5.49**	LxL	JRF-4xLCK-3003	-2.98*	LxA
Plant height (cm)	JRF-4xParvati	-19.32**	HxH	Polf-34xParvati	-16.63**	LxH
	EC-384154xParvati	-10.93**	LxH	H-25xParvati	-11.80**	HxH
	BAU-610AxLCK-3003	-6.56**	HxL	H-22xLCK-3003	-7.08**	AxL
No. of primary branches/plant	Polf-34xParvati	1.88**	AxA			
	JRF-4xPadmini	0.71**	AxA	EC-384154xPadmini	0.74*	LxA
	BAU-610AxLCK-3003	0.56*	HxL			
No. of capsules/ plant	H-25xLCK-3003	14.83**	LxH	JRF-4xParvati	7.93**	HxA
	EC-384154xPadmini	13.55**	AxA	EC-384154xPadmini	6.68**	AxL
	BAU-610AxLCK-3003	6.76*	HxH	EC-384154xShubhra	6.63**	AxA
Number of seeds/ capsule	H-25xParvati	1.01**	AxA	H-22xLCK-3003	0.80*	AxA
	BAU-610AxShubhra	0.70**	AxL			
	JRF-4xShubhra	0.62**	AxL			
1000-seed weight (g)	BAU-610AxShubhra	1.32**	HxL			
	H-22xParvati	1.20**	LxH	EC-384154xShubhra	0.46*	AxA
	JRF-3xPadmini	0.77**	HxA			
Seed yield/plant (g)	BAU-610AxShubhra	2.27**	HxL	EC-384154xShubhra	1.95**	LxH
	JRF-3xPadmini	2.16**	HxH	JRF-3xParvati	1.50**	HxL
	JRF-4xPadmini	1.89**	AxH	H-25xParvati	1.14**	AxL
Oil content (%)	Polf-34xParvati	1.69**	AxA	EC-384154xPadmi	1.50**	LxH
	H-22xLCK-3003	1.45**	LxA	JRF-4xParvati	1.31**	HxL
	BAU-610AxShubhra	1.36**	HxL	Polf-34xLCK-3003	1.18**	HxH
Incidence of *Alternaria blight* (0-5 Scale)	JRF-4xShubhra	-1.22**	HxH	H-22xPadmini	-0.39**	LxA
	Polf-34xLCK-3003	-0.91*	LxA	EC-384154xParva	-0.35*	HxH
	EC-384154xPadmini	-0.82*	AxL	EC-384154xShubhra	-0.33*	HxA

Where H= Good general combiner, L= Poor general combiner, A= Average general combiner

The analysis of variance for combining ability revealed highly significant differences among crosses for all the characters in F_1 and F_2 generations. The difference among lines (female) were significant for days to 50% flowering, days to maturity, plant height, number of primary branches/plant, number of seeds/capsule, 1000-seeds weight, seed yield/plant, oil content and incidence of *Alternaria* blight in F_1 and F_2 generations respectively. Whereas differences among testers (male) for all the characters in F_1 and F_2 generations were highly significant except days to maturity, number of seeds/capsule, 1000-seeds weight and incidence of *Alternaria* blight in F_2 generation.

The estimates of σ^2s were much higher than σ^2g for all the characters. The estimates of average degree of dominance indicated overdominance for all characters in F_1 and F_2 generations, except days to 50% flowering, number of primary branches/plant and plant height in F_2 generation which showed partial dominance.

On the basis of general combining ability effects, BAU 610-A, JRF-3, EC384154, Padmani and LCK-3003 were identified as most promising parents for seed yield and its contributing traits in F_1 whereas, H-22 was identified as best general combiner for least incidence of *Alternaria* blight. *in both F_1 and F_2 generations.*

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Productivity of summer groundnut, *Arachis hypogaea* L. as influenced by cumulative residual effect of crop residue incorporation and nitrogen management practices

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Abstract

Field experiments were conducted in the wetland farm of S.V. Agricultural College (Acharya N.G. Ranga Agricultural University), Andhra Pradesh for two consecutive years 2002-03 and 2003-04 to investigate the cumulative residual effect of incorporated crop residues and different nitrogen management practices applied to preceding lowland rice on the performance of succeeding groundnut and results revealed that cumulative residual effect of incorporation of fieldbean crop residues and supply of 100% N through FYM to rice has resulted in superior performance of groundnut crop compared to any other crop residue incorporation and nitrogen management practices adopted to preceding rice crop. However, similar magnitude of performance of groundnut was noticed with the combination of fieldbean crop residue incorporation and supply of 50% nitrogen each through fertilizer and FYM to preceding rice.

Key words: Groundnut, crop residue incorporation, nitrogen management practices nematode, groundnut

Introduction

In recent years the emphasis has been shifted from individual crop to cropping system as a whole since the response in component crop of the cropping system are influenced by the preceding crops and the inputs applied to them. Legume crop residues incorporated in to the field after harvesting seed can contribute considerable quantity of nitrogen to succeeding crops (Rekhi and Meelu, 1983). About less than 30% of nitrogen and small fractions of phosphorus and potash in organic manure may become available to immediate crop and rest to subsequent crop (Gaur and Singh, 1982). Conjunctive use of nutrients partly through organics and inorganics to preceding rice exhibited significant residual effect on succeeding groundnut (Thimmegowda and Devakumar, 1994). Rice-groundnut is one of the important cropping system in the southern agroclimatic zone region and maintenance of optimum soil fertility is an important consideration for obtaining higher and sustainable yield due to large turn over of nutrients in soil plant system. Since, the information on cumulative residual effect of crop residue incorporation and nitrogen management practices on groundnut grown after rice is lacking for southern agroclimatic zone of Andhra Pradesh, the present study was conducted to assess the effectiveness of cumulative residual effect of incorporation of crop residues, farm yard manure and fertilizer on dry matter production, nutrient uptake and pod yield of groundnut.

Materials and methods

Field investigations were conducted during 2002-03 and 2003-04 at wetland farm of S.V. Agricultural College, Tirupati (Andhra Pradesh). Soil analysis for physico-chemical properties was carried out initially, prior to the start of the experiment, by drawing soil samples at random from 0-30 cm depth of the experimental field. The results revealed that experimental field was sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen (160.8 kg/ha), medium in available phosphorus (25.6 kg/ha) and available potassium (175.4 kg/ha).

The experiment was laid out in a Randomized Bock Design with five replications. There were four treatments comprising of preceding crops to rice raised during *kharif* season *viz.*, C_1: Greengram, C_2: Clusterbean, C_3: Fieldbean, C_4: Cowpea whose crop residues (after picking the economic yield up to a common period of time of 75 days) are to be incorporated prior to transplanting of succeeding rice crop. Immediately after the last picking of the economic yield of respective crops up to 75 DAS, plants were uprooted from the entire plot area and weight of the four crop residues was recorded on fresh weight basis. At the time of termination of crops, they were at different post-flowering stages, possessing immature pods, flowers and even flower buds. Since, the crop residues have to be incorporated at a common point of time, all of them were removed without waiting for their full maturity. The crop residues thus obtained were chopped and incorporated in to their respective plots. Samples of all the crop residues were taken plot and replication wise, to estimate the nutrient content (Table 1) before incorporation. N, P and K contents of crop residues were

analysed by standard procedures outlined by Jackson (1973). The varieties of greengram, clusterbean, fieldbean, cowpea were LGG-407, Pusa Navabahar, HA-3 and CO-4, respectively.

Rice crop was raised during rabi season after harvest of preceding crops (raised during *kharif*) in the same layout, by sub-dividing each of the *kharif* treatments into four sub-plots, to which four nitrogen management practices were assigned. Rice was taken up in a Split Plot Design with incorporation of crop residues of four preceding crops to rice as main plot treatments *viz.*, C_1: incorporation of greengram crop residues, C_2: incorporation of clusterbean crop residues, C_3: incorporation of fieldbean crop residues and C_4: incorporation of cowpea crop residues and four nitrogen management practices imposed on rabi rice as sub-plot treatments *viz.*, N_1: No nitrogen, N_2:100% recommended nitrogen through fertilizer, N_3: 50% recommended nitrogen through fertilizer + 50% recommended nitrogen through farm yard manure, N_4: 100% recommended nitrogen through farm yard manure. The recommended dose of nutrients was 120 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha. The N content in FYM (Table 1) was taken into consideration and the quantity of FYM required for N_3 and N_4 treatments was calculated and incorporated in to the plots 10 days before transplanting of rice. For the treatments N_2 and N_3, fertilizer nitrogen in the form of urea was applied in three split doses of 50% as basal, 25% at active tillering and 25% at panicle initiation stages. A uniform dose of 80 kg P_2O_5 and 40 kg K_2O/ha was applied basally to all the treatments except to N_1, in the form of single super phosphate and murate of potash, respectively, after duly taking into consideration of phosphorus and potassium content of FYM in the FYM involved treatments. Test variety of rice was NLR 33359.

Table 1 Quantity of crop residues and nutrient content (%) of crop residues and FYM, incorporated before planting of rice

Source	2002-03				2003-04			
	Crop residues incorporated* (kg/ha)	N	P_2O_5	K_2O	Crop residues incorporated* (kg/ha)	N	P_2O_5	K_2O
FYM	--	0.50	0.20	0.51	--	0.50	0.20	0.51
Greengram residue*	7230	0.81	0.20	0.62	6970	0.83	0.21	0.64
Clusterbean residue*	13820	0.52	0.12	0.49	13100	0.54	0.14	0.51
Fieldbean residue*	16900	0.66	0.15	0.45	17200	0.65	0.16	0.44
Cowpea residue*	15440	0.61	0.14	0.50	15200	0.60	0.15	0.49

Groundnut crop was raised during summer season after the harvest of *rabi* rice in the same undisturbed layout of Split Plot Design, to study the cumulative residual effect of incorporation of crop residues of preceding crops to rice and N management practices imposed on rabi rice crop on the performance of succeeding groundnut. The layout of *rabi* rice crop was undisturbed, in which groundnut crop was sown. Each plot of *rabi* rice was ploughed using power tiller without disturbing the layout and plots were levelled individually using spades. No treatments were imposed to groundnut crop and the treatments consisted of the same those of rabi rice. Treatments consisted of cumulative residual effect of incorporation of crop residues of four preceding crops to rice as main plot treatments *viz.*, C_1: incorporation of greengram crop residues, C_2: incorporation of clusterbean crop residues, C_3: incorporation of fieldbean crop residues and C_4: incorporation of cowpea crop residues and residual effect of four nitrogen management practices imposed on *rabi* rice as sub-plot treatments *viz.*, N_1: No nitrogen, N_2:100% recommended nitrogen through fertilizer, N_3: 50% recommended nitrogen through fertilizer + 50% recommended nitrogen through farm yard manure, N_4: 100% recommended nitrogen through farm yard manure. Incorporation. Test variety of groundnut was K-134 a spanish bunch, suitable for cultivation in summer season. The seeds of groundnut were treated with mancozeb (3 g/kg seed) and used for sowing with a spacing of 22.5 x 10 cm between rows and plants. Sowing was done by hand dibbling. Intercultivation was done with star weeder at 20 and 40 days after sowing for controlling weeds in inter row spaces followed by hand hoeing for removal of intra row weeds. Plant samples collected for drymatter estimation at different growth stages of groundnut were oven dried, ground into fine powder and used for nutrient analysis. N, P and K contents of plant samples were analysed by the standard procedure out lined by Jackson (1973). The uptake of N, P and K in Kg/ha at different stages of crop growth was calculated by multiplying the nutrient content with the respective drymatter weights.

Results and discussion

Cumulative residual effect of crop residue incorporation and nitrogen management practices imposed on *rabi* rice has exerted marked influence on the growth (Table 2) and yield (Table 3) of succeeding groundnut. At all the crop growth stages of recording, plants of the tallest stature, highest LAI and drymatter production of groundnut were produced with the incorporation of crop residues of fieldbean (C_3) to preceding rice followed by cowpea, (C_4), clusterbean, (C_2) and greengram (C_1) residues, with significant disparity between any two of them and shortest plants were noticed with the incorporation of crop residues of greengram (C_1) to preceding rice, during both the years

of study (Table 2). This might be due to substantial amount of residual nutrients left by fieldbean crop residues to extend the favourable carry over effect on succeeding groundnut crop .The tallest plants, highest LAI and drymatter production of groundnut were produced with the supply of 100 % nitrogen through FYM (N_4) to preceding rice, which were comparable with 50% nitrogen each through fertilizer and FYM (N_3), but significantly superior to 100% nitrogen through fertilizer (N_2) and no nitrogen (N_1), which in turn were comparable between them and the shortest plants were noticed with non-supply of nitrogen (N_1) to preceding rice, during both the years of study. This might be due to the residual effect of FYM either alone or in combination with fertilizer nitrogen, which was comparatively higher than that of the exclusive inorganic source of nitrogen applied to preceding rice crop.

The highest number of pods/plant, hundred pod weight, hundred kernel weight, pod yield and haulm yield were produced with the incorporation of crop residues of fieldbean to rice (C_3) followed by cowpea (C_4), clusterbean (C_2) and greengram (C_1), with significant disparity between any two of them and the lowest number of pods/plant 100 pod weight, 100 kernel weight, pod yield and haulm yield was noticed with the incorporation of crop residues of greengram (C_1) to preceding rice, during both the years of study (Table 3). This might be due to residual and cumulative effect with the incorporation of fieldbean crop residues, which was comparatively higher than that of the other crop residue incorporation, with in the crop residues incorporation, differential residual response with different crop residues added can be attributed to their pattern of mineralization and decomposition.

Table 2 Growth of groundnut as influenced by cumulative residual effect of crop residue incorporation and nitrogen management practices to preceding rice

Treatment	Plant height (cm)				Leaf area index				Dry matter production (kg /ha)			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
Cropping system, 2003 -2004												
Incorporation of crop residues												
C_1: incorporation of greengram crop residues	6.5	13.7	23.4	30.6	0.49	1.60	2.72	2.35	489	2170	3888	5195
C_2: incorporation of clusterbean crop residues	6.7	15.8	25.6	32.7	0.49	1.64	2.96	2.59	556	2426	4212	5608
C_3: incorporation of fieldbean crop residues	7.2	20.3	30.0	36.4	0.60	1.73	3.43	3.06	689	2923	4779	6517
C_4: incorporation of cowpea crop residues	6.9	18.0	27.8	34.6	0.54	1.69	3.20	2.82	626	2677	4552	6067
SEm±	0.05	0.6	0.7	0.65	0.01	0.01	0.06	0.08	18.3	85.0	87.0	123.4
CD (P=0.05)	0.1	1.5	1.8	1.6	0.04	0.03	0.14	0.21	45	208	215	302
Nitrogen management practices												
N_1: No nitrogen	6.5	13.7	22.2	27.6	0.44	1.59	2.74	2.29	506	2119	3818	5200
N_2: 100% recommended nitrogen through fertilizer	6.6	15.3	23.8	29.2	0.48	1.62	2.87	2.52	545	2371	4086	5582
N_3: 50% recommended nitrogen through fertilizer + 50% recommended through farm yard manure	7.0	18.6	29.6	37.9	0.56	1.70	3.29	2.94	634	2730	4635	6119
N_4: 100% recommended nitrogen through farm yard manure	7.2	20.3	31.2	39.7	0.59	1.73	3.42	3.07	675	2970	4892	6488
SEm ±	0.07	0.9	1.04	0.92	0.02	0.02	0.08	0.12	26.0	120.2	124.2	174.5
CD (P=0.05)	0.2	1.8	2.1	1.9	0.05	0.04	0.17	0.25	54	248	275	360
Cropping system, 2004-2005												
Incorporation of crop residues												
C_1: incorporation of greengram crop residues	6.3	14.9	22.3	30.0	0.46	1.59	2.83	2.26	509	2231	4196	5073
C_2: incorporation of clusterbean crop residues	6.7	16.9	24.2	31.6	0.51	1.63	3.16	2.53	574	2447	4479	5501
C_3: incorporation of fieldbean crop residues	7.3	20.3	29.0	35.3	0.61	1.71	3.53	3.02	574	2895	4971	6223
C_4: incorporation of cowpea crop residues	7.0	18.4	26.4	33.5	0.56	1.68	3.35	2.78	641	2671	4738	5930
SEm ±	0.06	0.6	0.7	0.61	0.02	0.008	0.06	0.09	23.7	80.1	100.5	113.6
CD(P=0.05)	0.1	1.4	1.7	1.5	0.04	0.02	0.17	0.24	58	196	236	278
Nitrogen management practices												
N_1: No nitrogen	6.5	14.7	21.7	27.1	0.46	1.59	2.83	2.18	523	2167	4095	5022
N_2: 100% recommended nitrogen through fertilizer	6.6	16.2	22.7	28.5	0.49	1.61	3.00	2.45	572	2388	4346	5346
N_3: 50% recommended nitrogen through fertilizer + 50% recommended through farm yard manure	7.1	19.2	27.8	36.6	0.57	1.69	3.43	2.88	648	2748	4854	6019
N_4: 100% recommended nitrogen through farm yard manure	7.2	20.5	29.6	38.2	0.61	1.72	3.62	3.07	689	2941	5089	6342
SEm±	0.08	0.8	0.9	0.86	0.02	0.01	0.09	0.14	34.1	113.2	142.1	174.5
CD (P=0.05)	0.2	1.7	2.0	1.8	0.05	0.03	0.2	0.28	70	234	293	360

Table 3 Yield attributes, pod yield and economics of groundnut as influenced by cumulative residual effect of crop residue incorporation and nitrogen management practices to preceding rice

Treatments	Number of pods/ plant	100 pod weight (g)	100 kernel weight (g)	Pod yield (kg /ha)	Haulm yield (kg/ ha)	Shelling percentage	Harvest index*	Gross returns (Rs/ ha)	Net returns (Rs/ha-)	Benefit-cost ratio
Cropping system, 2003-2004										
Incorporation of crop residues										
C_1: incorporation of greengram crop residues	10.0	74.1	30.0	1898	3604	72.8	34.23	25034	14384	2.35
C_2: incorporation of clusterbean crop residues	10.7	76.6	31.8	2063	3956	72.9	34.08	27215	16565	2.56
C_3: incorporation of fieldbean crop residues	12.2	81.4	35.5	2393	4737	73.5	33.39	31583	20933	2.97
C_4: incorporation of cowpea crop residues	11.5	79.0	33.7	2228	4388	73.2	33.47	29403	18753	2.76
SEm±	0.24	0.86	75.6	75.6	97.2	0.94	—	887	0842	0.08
CD (P=0.05)	0.6	2.1	185	185	238	NS	---	2172	1864	0.19
Nitrogen management practices										
N_1: No nitrogen	9.7	73.9	29.5	1696	3745	72.2	31.19	22429	11779	2.11
N_2: 100% recommended nitrogen through fertilizer	10.1	75.6	30.8	1911	3920	72.6	32.84	25242	14592	2.37
N_3: 50% recommended nitrogen through fertilizer + 50% recommended through farm yard manure	12.0	80.0	34.7	2379	4384	73.4	35.23	31372	20722	2.95
N_4: 100% recommended nitrogen through farm yard manure	12.6	81.7	35.9	2594	4634	74.3	35.92	34192	23542	3.21
SEm±	0.35	1.21	106.9	106.9	137.5	1.17	---	1688	1642	0.15
CD (P=0.05)	0.7	2.5	220	220	284	NS	---	2854	2672	0.27
Cropping system, 2004-2005										
Incorporation of crop residues										
C_1: incorporation of greengram crop residues	9.1	72.9	29.1	1743	3395	73.2	33.85	23005	12355	2.16
C_2: incorporation of clusterbean crop residues	9.9	75.7	30.9	1938	3762	73.3	33.79	25577	14927	2.40
C_3: incorporation of fieldbean crop residues	11.5	80.6	34.6	2328	4540	73.6	33.77	30725	20075	2.88
C_4: incorporation of cowpea crop residues	10.6	78.4	32.7	2133	4184	73.5	33.59	28154	17504	2.64
SEm±	0.16	0.78	0.65	78.4	88.2	0.82	---	937	902	0.09
CD (P=0.05)	0.4	1.9	1.6	192	216	NS	---	2294	2014	0.23
Nitrogen management practices										
N_1: No nitrogen	8.9	72.9	28.5	1633	3546	72.6	31.52	21590	10940	2.03
N_2: 100% recommended nitrogen through fertilizer	9.3	74.7	29.7	1798	3723	73.1	32.76	23753	13103	2.23
N_3: 50% recommended nitrogen through fertilizer + 50% recommended through farm yard manure	11.2	79.2	33.7	2243	4187	73.7	34.90	29584	18934	2.78
N_4: 100% recommended nitrogen through farm yard manure	11.6	81.0	35.3	2468	4426	74.3	35.82	32533	21883	3.05
SEm±	0.23	1.10	0.92	110.9	124.8	1.02	---	1814	1794	0.18
CD (P=0.05)	0.5	2.3	1.9	229	258	NS	---	3140	2942	0.29

Supply of 100% nitrogen through FYM (N_4) to preceding rice resulted in the production of highest number of pods/plant, 100-pod weight, 100-kernel weight as well as pod yield and haulm yield, which was comparable with 50% nitrogen each through fertilizer and FYM (N_3), but significantly superior to 100% nitrogen through fertilizer (N_2) and no nitrogen (N_1), which were comparable between them and the lowest number of pods/plant, 10 pod weight, 100 kernel weight, pod yield and haulm yield were noticed with non-supply of nitrogen (N_1) to preceding rice, during both the years of study. This might be due to the residual effect of FYM either alone or in combination with fertilizer nitrogen, which was comparatively higher than that of the exclusive inorganic source of nitrogen applied to preceding rice crop. During both the years of study, shelling percentage of groundnut did not show any significant variation due to residual and cumulative effect of either incorporation of different crop residues or varied nitrogen management practices tried on preceding rice. Harvest index of groundnut was not altered to a statistically noticeable extent either by incorporation of different crop residues or nitrogen management practices to preceding rice. However, the highest value of harvest index was recorded with incorporation of fieldbean crop residues (C_3) in combination with the supply of 100% nitrogen through FYM (N_4) to preceding rice, while it was the lowest with incorporation of greengram crop residues (C_1) without any nitrogen supply (N_1). In the present study, the residual effect of organic source at higher proportion was evident from higher leaf area index, drymatter accrual, number of pods/plant, 100 pod weight, 100 kernel weight, pod and haulm yield. This clearly indicates that organic source at higher proportion can sustain the nutrient status of soil to produce reasonable residual effect. Organic source of

nitrogen, besides supplying nutrients to the current crop, quite often leave substantial residual effect on succeeding crops in the cropping system. These results are in accordance with the findings of Maskina and Meelu (1984). Significant carry over effect due to substitution of nitrogen with higher proportions of organic sources to rice crop on the succeeding crops was also reported by Thimmegowda and Devakumar (1994) and Paulraj and Velayudham (1995). Residual effect of fertilizer nitrogen applied to rice was not traceable on the succeeding groundnut crop as exhibited in the present study corroborates the findings of Ramaseshaiah *et al.* (1985).

The highest gross returns, net returns and benefit-cost ratio of groundnut were realized with cumulative residual effect of incorporation of fieldbean crop residues (C_3) to rice were due to higher pod and haulm yield realized by this treatment followed by cowpea (C_4) and clusterbean (C_2), with significant disparity between any two of them, while they were found to be the lowest with the residual and cumulative effect of incorporation of greengram crop residues (C_1) to preceding rice, during both the years of study (Table 3). The highest gross returns, net returns and benefit-cost ratio of groundnut were realised with the residual and cumulative effect of 100% nitrogen through FYM (N_4) applied to preceding rice, which were comparable with residual and cumulative effect of 50% nitrogen each fertilizer and FYM (N_3) but significantly superior to 100% nitrogen through fertilizer (N_2) and no nitrogen (N_1), which were comparable between them and the lowest gross returns, net returns and benefit-cost ratio were recorded with the residual and cumulative effect of non-supply of nitrogen (N_1) applied to preceding rice and also since groundnut crop raised as residual crop, the cost of cultivation did not differ among the treatments.

Based on the out come of the investigation, it could be inferred that by raising a reasonably short duration leguminous crop (either a pulse crop or vegetable crop depending up on the farming situation) preceding to rice and incorporation of the crop residues after picking the economic yield and supply of 50% recommended dose of nitrogen each through fertilizer and FYM to rice followed by raising groundnut as residual crop, to utilize the residual fertility was found the best integrated nitrogen management package for rice-groundnut cropping system to achieve higher growth, productivity and economic returns of succeeding groundnut.

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Yield attributes, yield, quality and uptake of nutrients by summer groundnut, *Arachis hypogaea* L. as influenced by sources and levels of sulphur under varying irrigation schedules

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Abstract

The response of summer groundnut Cv. GG-2 to sources and levels of sulphur under varying irrigation schedules was studied on loamy sand soils at Main Castor-Mustard Research Station, S.D.A.U., Sardarkrushinagar during 2003 and 2004. Pooled data indicated that irrigation scheduled at 40 mm CPE significantly improved the yield attributes, pod and haulm yield, quality of groundnut and uptake of nutrients (NPS). Maximum WUE was achieved with irrigation schedule of 50 mm CPE. Sources of sulphur had non-significant effect on yield, quality and uptake of nutrients (NPS) by groundnut.

Key words: Groundnut, irrigation schedules, yield attributes, quality, sulphur

Introduction

In Gujarat, groundnut is largely grown under rainfed condition and yield is influenced due to erratic monsoon, the scope of increasing area under *kharif* groundnut is limited. Due to favorable climatic condition in North Gujarat, summer groundnut in the loamy sand soil provides assured production than the rainy season crop. There is a vast scope to expand groundnut area during summer season in North Gujarat with the availability of Narmada irrigation water in near future. However, the yield potential of this crop grown during summer can be realized to a greater extent by adopting suitable water and nutrient management practices (Gosh *et al.*, 2001). Irrespective of crops, sulphur is now rightly called the fourth major plant nutrient, next only to N, P, and K but for oilseed crops it is as important as phosphorus. Patel *et al.* (1986) while reporting the available S status of the soils in Gujarat indicated the average per cent deficiency of 38.3 in South Gujarat, 42.0 in middle Gujarat, 44.3 in North Gujarat and 25.0 in Saurashtra and Kachchh. Summer groundnut is likely to find the place in the cropping system in light texture soils under assured irrigation facilities in the arid and semi-arid parts of Gujarat. Lack of information on sulphur and water management in summer groundnut led to plan this investigation.

Materials and methods

A field experiment was conducted at Main Castor- Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat during summer seasons of 2003 and 2004. The soil of the experimental plot was loamy sand and slightly alkaline in reaction (pH 7.9), having low organic carbon, available N, high in available phosphorus, medium in available potassium, and low in sulphur (7 ppm). The experiment comprised of three main plot treatments of irrigation schedules *viz.*, I_1: 40 mm CPE, I_2: 50 mm CPE and I_3: 60 mm CPE and seven sub-plot treatments in combination of sources (C_1: elemental sulphur and C_2: gypsum) and levels of sulphur (0, 20, 40 and 60 kg S/ha) was laid out in Split Plot Design and replicated four times. Three common irrigations were followed for proper germination and establishment of the plants. The seeds were drilled at 30cm apart during first half of February. Common dose of 25 kg N and 50 kg P_2O_5/ha was applied in the form of DAP and urea as basal. Elemental sulphur and gypsum were applied 21 days prior to sowing as per treatment as basal. Oil content in the kernel was estimated by Nuclear Magnetic Resonance Spectrophotometer (NMRS). Whereas N, P and S content from kernels, haulms and shells were determined employing standard methods.

Results and discussion

Irrigations scheduled at 40 mm CPE (I_1), showed its superiority for improving number of pods/plant, pod weight/plant, shelling percentage and 100 kernels weight as well as, pod and haulm yield of groundnut (Table 1). Application of frequent irrigations (40 mm CPE, I_1) led to higher pod yield due to improvement in yield attributes *viz.*, number and weight of pods, kernel weight and shelling percentage. Moreover, accumulation of more photosynthates has helped better pod filling in summer groundnut. The results corroborate with the findings of Shaikh *et al.* (2004) and Raskher and Bhoi (2003) indicating that scheduling of irrigation at 75mm CPE improved yield parameters as compared to that of 100 and 125 mm CPE.

The sources of sulphur had no significant effect on the yield attributes as well as on pod and haulm yield of groundnut (Table 1). This is ascribed to similar response of both sources on growth and yield parameters of groundnut. Similar findings have been reported by Kumar *et al.* (2001) for sources of sulphur (gypsum, elemental sulphur and pyrite) in mustard.

Both levels of sulphur (40 and 60 kg) did not vary from each other in respect to production of number of pods, 100 kernel weight and weight of pods per plant showed superiority over lower levels. However, application of S irrespective of dose significantly increased shelling percentage over no sulphur application. A linear increase in pod and haulm yield was observed up to 40 kg S/ha. It increased pod yield over 0 and 20 kg/ha to the tune of 19.90 and 8.34% whereas for haulm yield the corresponding values were 13.49 and 6.45%, respectively. The increase in pod and haulm yield is mainly ascribed to *improvement in yield attributes with S application in* addition to its multiple role in metabolism as an essential constituent of amino acids and also improvement in vegetative structure, production of reproductive structures and assimilates thereby maintaining balance source sink. These results are in close conformity with the findings Nayak *et al.* (2004). The interactive effect of irrigation schedules and sulphur levels was found significant on pod yield. The treatment combination I_1S_2 standing at par with I_1S_3 (40mm CPE and 40 kg S/ha) registered significantly higher pod yield than rest of the treatment combinations. This indicated that supply of more than 40 kg did not respond under adequate irrigations. It sufficed the need of summer groundnut on S deficient soils.

Quality: Irrigation schedules had no significant effect on oil content of groundnut (Table 1). However, the oil yield was positively improved with scheduling of irrigations is attributed to increased pod yield and 100 kernel weight. These results are in line with the findings reported by Dodia (1985). The protein content and protein yield were also significantly influenced due to irrigation schedules. The highest protein content was noticed with lower rate of irrigation (I_3) and the reverse was found true for frequent irrigations (I_1). This is mainly due to increase in nitrogen content in kernels produced with lower rate of irrigation (I_3).

Application of sulphur brought significant improvement in quality of groundnut. Significantly higher oil content and oil yield were found with 60 kg S/ha than lower levels of S but it was at par with 40 kg S/ha in case of oil yield. The increase in oil content might be due to S application as it is required for synthesis of S containing amino acids, protein and oils. The highest oil yield was recorded with higher rate of sulphur (60 kg/ha) is attributed to high oil *content and pod yield (Table 1) by respective treatment.*

The significant positive response of each level of sulphur was observed on protein content. Similar trend as that of oil yield was observed for protein yield with application of sulphur (Table 1). This is contributed to increase in protein content and pod yield (Table 1) as well as nitrogen uptake by groundnut crop (Table 2) with S application, as nitrogen is an integral part of chlorophyll and also a major content of protein. The interaction effect of irrigation schedules and sulphur levels was found significant in case of oil and protein yield. The treatment combination I_1S_2 (40 mm CPE and 40 kg S/ha) was found at par with I_1S_2 (40 mm CPE and 60 kg S/ha) and produced significantly higher oil as well as protein yield than rest of the treatment combinations.

Table 1 Effect of irrigation schedules, sources and levels of sulphur on yield attributes, yield and quality of groundnut (pooled)

Treatments	Pods/plant	Shelling percentage	100 kernel weight (g)	Weight of pods/plant (g)	Pod yield (kg/ha)	Haulm yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	Protein content (%)
Irrigation schedules									
I_1: 40mm CPE	32	75.48	37.54	23.5	3784	6040	48	1363	24
I_2: 50mm CPE	31	75.15	36.38	20.9	3475	5546	48	1263	24
I_3: 60mm CPE	30	74.79	35.00	18.9	3156	5187	49	1144	24
CD (P=0.05)	0.7	0.24	0.46	0.6	234	290	NS	19	0.06
Sulphur sources									
C_1: Elemental S	31	75.21	36.29	21.0	3462	5598	48	1249	24
C_2: Gypsum	31	75.07	36.33	21.1	3482	5583	49	1265	24
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sulphur levels									
S_0: Control	27	74.29	33.05	17.2	3085	5161	47	1051	23
S_1: 20 kg/ha	31	75.29	35.98	20.9	3414	5502	48	1238	24
S_2: 40 kg/ha	33	75.57	38.17	23.1	3699	5857	49	1366	24
S_3: 60 kg/ha	33	75.43	38.04	23.1	3688	5843	49	1371	24
CD (P=0.05)	3.2	0.42	0.49	1.3	89	117	0.3	122	0.01

Table 2 Effect of irrigation schedules, sources and levels of sulphur on nutrient uptake, water use, water use efficiency (WUE) and economics of groundnut (pooled)

Treatments	Nutrient uptake (kg/ha)			WUE (kg/ha/mm)	Net return (Rs/ha)	Net ICBR
	N	P	S			
Irrigation schedules						
I_1: 40mm CPE	194	28	18	4.8	50282	1:5.56
I_2: 50mm CPE	181	27	17	4.7	47084	1:7.37
I_3: 60mm CPE	168	25	16	4.4	40687	-
CD (P=0.05)	9.9	1.4	0.8	-	-	-
Sulphur sources						
C_1: Elemental S	181	27	17	4.6	45174	-
C_2: Gypsum	181	27	17	4.6	45738	-
CD (P=0.05)	NS	NS	NS	-	-	-
Sulphur levels						
S_0: Control	155	23	14	4.0	38875	-
S_1: 20 kg/ha	177	26	16	4.6	44534	1:29.78
S_2: 40 kg/ha	195	29	18	4.9	49522	1:40.55
S_3: 60 kg/ha	197	29	19	4.9	49181	1: -2.38
CD (P=0.05)	15.1	1.7	1.4	-	-	-

Table 3 Interaction effect of irrigation schedules and sulphur levels on pod, oil and protein yield (pooled)

Treatments	Pod yield (kg/ha)				Oil yield (kg/ha)				Protein yield (kg/ha)			
	S_0	S_1	S_2	S_3	S_0	S_1	S_2	S_3	S_0	S_1	S_2	S_3
I_1: 40mm CPE	3339	3697	4073	4026	1094	1344	1512	1503	563	650	737	734
I_2: 50mm CPE	3082	3386	3717	3716	1069	1228	1372	1383	525	606	675	681
I_3: 60mm CPE	2834	3159	3308	3323	992	1143	1213	1228	493	565	603	606
CD (P=0.05)	80				74				50			

Irrigation schedule I_1 (40mm CPE) recorded significantly the highest value of N,P and S uptake by groundnut (Table 2). This is ascribed to higher yield (Table 1) with frequent irrigations as well as improvement of nutrient availability under conducive soil environment. Similar findings have been reported by Bharambe *et al.* (2004). With respect to removal of nitrogen, phosphorus and sulphur by groundnut, none of the sources of sulphur had pronounced effect. This is mainly due to even influence of sources on the concentration of N, P and S in kernels, haulm and shell as well as on pod and haulm yield. Successive increase in sulphur application up to 40 kg/ha realized remarkable improvement in N, P, and S uptake by the crop. This could be ascribed to higher nitrogen, phosphorus and sulphur content in kernels, haulm and shell, besides higher pod and haulm yield with higher level of sulphur. The results are in accordance with those reported by Nayak *et al.* (2004). WUE was increased with decrease in irrigation schedules. The highest WUE (4.76 kg/ha.mm) was achieved with 40mm CPE (I_1). Similarly the highest WUE (4.92 kg/ha mm) being with 60 kg S/ha, was almost equal as that with 40 kg S/ha (Table 2). Net realization accrued from I_1 (40mm CPE) was much higher than 50 (I_2)and 60mm CPE (I_3). However, net ICBR value was highest with 50mm CPE. Similarly higher net return and net ICBR values were obtained with 40 kg S/ha. Application of sulphur through gypsum was found more advantageous. The findings of the investigation indicated that irrigations scheduled at 40 mm CPE (17 irrigations) with 50mm depth of water in summer groundnut supplying 40 kg S/ha through gypsum or elemental sulphur was found more effective and economically viable in loamy sand soils of semi-arid parts of North Gujarat region.

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Effect of spacing and nitrogen levels on *rabi* castor, *Ricinus communis* Linn. grown under different cropping sequences in North Gujarat agro-climatic conditions

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Abstract

Studies on the effect of spacing and nitrogen levels on rabi castor grown under different *rabi* castor based cropping sequences were conducted during 2003-04 and 2004-05. The results revealed that among different *kharif* crops, clusterbean grown as green manure recorded remarkably higher seed yield, stalk yield, net realization and BCR as compared to rest of the *kharif* crops. In case of spacings, 90 cm x 45 cm recorded significantly higher seed and stalk yields than 90 cm x 60 cm. Net realization was not affected due to different spacings. Application of 120 kg N/ha produced remarkably higher seed yield over 40 and 80 kg N/ha. Among different sequences, greengram - castor gave the highest net realization, BCR, system productivity and system profitability.

Key words: *Rabi* castor, system productivity, system profitability, cropping sequence

Introduction

Castor (*Ricinus communis* L.) is the most important non-edible oilseed crop. In Gujarat, it is grown over an area of 3.58 lakh ha producing about 7.08 lakh tonnes with an average productivity of 1978 kg/ha (2007-08). There is a greater scope of growing castor in *rabi* season. Therefore, there are possibilities to take any short duration crop in *kharif* season before growing of *rabi* castor. Development of dairy industries in North Gujarat has created the demand for forage to nourish milch animals. Double cropping system involving cultivation of *rabi* castor after suitable *kharif* crops can solve the food and fodder requirements of farmers and increase the overall income. Fodder sorghum and greengram are important short duration *kharif* crops of the region can successfully be cultivated before *rabi* castor. The beneficial effect of green manure to improve the yield of succeeding crop and soil nutrient status of the soil is well known (Rajaram *et al.*, 2003).

Materials and methods

A field experiments were conducted at the Agronomy Instructional Farm, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushingar on the most profitable *rabi* castor based cropping system and to study the effect of *kharif* crops on spacing and nitrogen requirement of *rabi* castor during *kharif* and *rabi* seasons 2003-04 and 2004-05. The soil of the experimental sites was loamy sand in texture having pH of 7.6, organic carbon 0.17, available nitrogen 179 kg/ha, 40 kg/ha available phosphorus and 184 kg/ha available potash. The experiment was laid out in Split Plot Design with four replications keeping *kharif* crops *viz.*, clusterbean as green manure, greengram, fodder sorghum and fallow in main plots and combinations of spacings (90 cm x 60 cm and 90 cm x 60 cm) and nitrogen levels (40, 80 and 120 kg N/ha) in subplots. The *kharif* crops were grown at the onset of monsoon and castor was sown on 7th and 9th, October of 2003 and 2004, respectively. All the *kharif* crops were raised with recommended package of practices. All the plots were uniformly fertilized with 60 kg P_2O_5/ha as basal at the time of sowing of castor, while half dose of nitrogen was applied as basal and remaining half dose was applied in two equal splits at 30-33 and 80-85 days after sowing (DAS). The rainfall received during 2003-04 and 2004-05 was 691.8 and 250.6 mm with 31 and 20 rainy days, respectively.

Results and discussion

Kharif crops

Clusterbean grown as green manure added an average of 20.9 t/ha green biomass in the soil (Table 1). Greengram produced on an average of 1274 and 1715 kg/ha of seed and fodder while, fodder sorghum gave 24.95 and 7.85 tonnes/ha of green and dry fodder, respectively.

Rabi castor

Effect of *kharif* crops: The pooled results revealed that different *kharif* crops influenced the seed and stalk yields of castor significantly. Higher seed and stalk yields of castor were produced when it was grown after green manure than grown after greengram, fodder sorghum or on fallow land. The increase in seed yield of castor grown after green manure was to the tune of 14.1, 30.7 and 20.1% over greengram, fodder sorghum and fallow, respectively. This could be attributed to the favourable condition prevailing for growth and development of castor grown after green manuring, which improves the physical,

chemical and biological environments of soil. Fodder sorghum being an exhaustive crop, produces huge quantity of fodder and thereby removes large amount of nutrients from the soil, thus resulted in poor growth and development of succeeding crop grown after fodder sorghum as compared to grown after green manure, greengram and fallow. These results are in agreement with the finds of Kumpawat and Rathore (2003) and Mishra and Giri (2004).

Effect of spacing: The seed and stalk yields were remarkably increased with the decrease in spacing. The magnitude of increase in seed yield of castor under 90 cm x 45 cm spacing was to the tune of 4.1% over 90 cm x 60 cm spacing. The higher seed and stalk yields recorded with 90 cm x 45 cm spacing was mainly attributed to the fact that this spacing acquired 33.3% higher plant population than 90 cm x 60 cm spacing.

Effect of nitrogen: The different doses of nitrogen influenced the seed and stalk yields of castor significantly. Fertilizing castor with 120 kg N/ha recorded significantly higher seed and stalk yields over 40 and 80 kg N/ha (Table 2). The probable reason for such a positive response due to addition of higher rate of nitrogen might be tended to put more vegetative growth, better root development and resulted in efficient photosynthesis and finally produced more seed yield. The maximum mean net monetary realization was registered with greengram cultivation over fodder sorghum, however monetary loss was recorded with green manure practice. In case of BCR, the highest value (3.16) was observed under greengram followed by fodder sorghum (1.06). Significantly the highest net realization with BCR (2.37) were registered when castor was grown after green manure. While, minimum net realization and BCR (1.58) was recorded after fodder sorghum. Net realization received from castor was not influenced significantly due to spacings, while the net realization secured from castor was significantly dose depended.

The castor equivalent yield, net realization, system productivity and system profitability obtained from different crop sequences indicated that the highest castor equivalent yield, total net realization, system productivity, system profitability and BCR (2.35) were received under green gram-castor sequence while, fallow-castor sequence recorded the minimum, net realization, system productivity and system profitability (Table 3).

Table 1 Grain/fodder/stover yield and economics of *kharif* crops (pooled)

Crops	Yield (kg/ha)		Gross realization	Cost of cultivation	Net realization	BC
	Seed	Green biomass/stover/dry fodder	(Rs/ha)	(Rs/ha)	(Rs/ha)	ratio
Green manure	--	20900	--	5,898	(-)5,898	-
Greengram	1,274	1,795	28,173	6,768	21,405	3.16
Fodder sorghum	--	7,850	15,700	7,615	8,085	1.06
Fallow	--	--	--	--	--	--

Table 2 Seed and stalk yield and economics of castor (pooled)

Treatment	Yield (kg/ha)		Gross realization	Cost of cultivation	Net realization	BC ratio
	Seed	Stalk	(Rs/ha)	(Rs/ha)	(Rs/ha)	
Main plot treatments - *Kharif* crops						
Green manure	3,185	4,340	45,677	13,573	32,104	2.37
Greengram	2,794	3,848	40,080	13,573	26,507	1.95
Fodder sorghum	2,436	3,307	35,017	13,573	21,444	1.58
Fallow	2,651	3,513	37,997	13,573	24,424	1.80
SEm ±	47	72	-	-	658	-
CD (P=0.05)	141	214	-	-	1,955	-
Sub-plot treatments: Spacing x Nitrogen - Spacings						
90 cm x 60 cm	2,711	3,654	38,871	12,986	25,885	1.99
90 cm x 45 cm	2,825	3,850	40,512	14,159	26,353	1.86
SEm ±	28	39	-	-	387	-
CD (P=0.05)	77	108	-	-	NS	-
Nitrogen levels : (kg/ha)						
40	2,434	3,354	34,914	13,060	21,854	1.67
80	2,841	3,824	40,928	13,581	27,347	2.01
120	3,015	4,078	43,232	14,077	29,155	2.07
SEm ±	34	48	-	-	475	-
CD (P=0.05)	95	132	-	-	1,329	-

Table 3 Economics, system productivity and system profitability of different crop sequences (pooled of two years)

Crop sequence	Castor EY (kg/ha)	Gross realization (Rs/ha)	Cost of cultivation (Rs/ha)	Net realization (Rs/ha)	System productivity (kg/ha/day)	System profitability (Rs/ha/day)	BC ratio
Green manure-castor	3262	45,673	19,471	26,202	8.94	71.79	1.34
Greengram -castor	4875	68,253	20,341	47,912	13.36	131.27	2.35
Fodder sorghum - castor	3622	50,712	21,187	29,525	9.92	80.89	1.40
Fallow- castor	2714	37,997	13,573	24,425	7.44	66.92	1.80

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Effect of potassium fertilization on cationic nutrient content and uptake in seeds of two castor, *Ricinus communis* L. cultivars

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Abstract

Field experiments were conducted with castor variety DCS-9 and hybrid DCH-32 during the *kharif* season of 2004, in red sandy loam (Alfisol) soil having initial available potassium 202 kg K_2O/ha, under rainfed conditions. Potash treatments comprised 7 levels *viz.*, 0, 20, 40, 60, 80, 100 and 120 kg K_2O/ha. Results showed that castor seed yield responded positively to the potassium (K) doses and optimum doses of K derived with linear response plateau equation were 87 (r^2 = 0.98) for DCS-9 variety and 72 (r^2 = 0.79) kg K_2O/ha for DCH-32 hybrid. Cationic nutrient content and uptake in the seeds followed the order K > Mg > Ca > Fe > Zn > Cu > Mn irrespective of cultivar. Further, the K fertilization has influenced the Mg, Fe, Mn and Cu uptake in DCS-9 seed while Mg and Cu uptake in DCH-32 seed. The boundary line technique showed the internal nutrient requirement ratios, Ca: K, Mg: K, Fe: K, Zn: K, Mn: K and Cu: K associated with 94% of relative seed yield to be 0.049, 0.495, 0.050, 0.0057, 0.0024 and 0.0034 for DCS-9 and 0.084, 0.613, 0.072, 0.0094, 0.0030 and 0.0061 for DCH-32 respectively. The significance of these results is that the analysis of seed has a good potential as a diagnostic tool for evaluating mineral nutrition of castor.

Key words: Castor cultivars, cationic nutrient content and uptake, internal nutrient ratio, potassium fertilization, seed analysis

Introduction

Castor (*Ricinus communis* L) is an industrial oilseed crop. In Andhra Pradesh, it is cultivated under rainfed conditions in red sandy loam (Alfisol) soils. These soils are inherently low in essential nutrients (Katyal, et al., 1997; Dar, 2004). Under intensive cultivation, positive response to potassium (K) application has been reported in castor (Murthy, 2001), indicating the plausible inadequacy of available K in these soils. Plant analysis is one of the important diagnostic tools to identify nutrient deficiency, sufficiency, and toxicity. Timely corrective measures either to crop or soil are imperative to sustain higher crop yields. Seed analyses have been used to determine the nutrient requirement of crops and uptake from the soils (Moussavic-Nik, 1997; Murthy and Muralidharudu, 2003). Advantages of seed as diagnostic tissue is that they can be easily secured, cleaned and processed. Low nutritional status of seeds has been reported to reduce plant growth under conditions of low nutrient availability (Mengel and Kirkby, 1987). Genotypic variation in nutrient content of seed reflects the capability of cultivar to extract and accumulate nutrients from the soil. Present study was conducted to know the cationic nutrient content and uptake in seed of castor cultivars as influenced by K fertilization and to establish internal nutrient ratio requirements.

Materials and methods

Field experiments were conducted separately at Directorate of Oilseeds Research, Rajendranagar, Hyderabad, research farm with castor variety DCS-9 and hybrid DCH-32 as test crops during *kharif*, 2004, in red sandy loam (Alfisol) soil under rainfed conditions. Physico-chemical properties of the soil were pH 7.9, E.C 0.11 d S/m, Org. C 3.5 g/kg, cation exchange capacity 9.3 c mol (p+)/kg, available N 180, P_2O_5 12 and K_2O 202 kg/ha. DTPA extractable micronutrients *viz.*, Fe, Zn, Mn and Cu in soil were 2.53, 0.57, 7.20 and 0.62 mg/kg respectively. The treatments comprised 7 levels *viz.*, 0, 20, 40, 60, 80, 100 and 120 kg K_2O/ha supplied through muriate of potash and phosphorus @ 40 kg/ha as basal doses to all the plots. Recommended dose of N (60 kg/ha) in three splits was applied to each castor cultivar. Experiments were conducted in RBD and replicated thrice. The spacing was 90 x 60 cm. Recommended crop husbandry practices were followed. Soil samples were collected from the experimental plots on 45th day after sowing at primary spike initiation stage and analysed for available potassium content with 1N ammonium acetate extractant as per the standard procedure. Calcium and magnesium content in the soil were determined by Versenate method. The available Zn, Fe, Cu and Mn in the soil samples extracted with DTPA solution (Lindsay and Norvell, 1978) were analysed using atomic absorption spectrophotometer (AAS - GBC 332 model). Seed samples collected at maturity, from the three picks (primary, secondary and tertiary) were composited and digested in 9:4 HNO_3: $HClO_4$ diacid. Potassium concentration in the acid digest aliquot was analysed by flame photometer. Calcium, magnesium, iron, zinc,

manganese and copper concentrations were analysed with AAS.

Internal nutrient requirements of the nutrient ratio in seed, which were sufficient for 94% maximum yield, instead of 95% (Fox *et al.*, 1986) were determined from graphs of relative yield versus nutrient ratios using boundary line technique (Webb, 1972). For brevity, one graph each for DCS-9 and DCH-32 are presented in Fig.1 and Fig.2, respectively.

Results and discussion

Seed yield: Castor cultivars showed significant variation in seed yields due to K fertilization. Seed yield of castor variety DCS-9 and DCH-32 varied from 852.2 to 1304.4 kg/ha and 871.1 to 1302.2 kg/ha respectively among the K doses. In the present study, optimum doses of K derived with linear response plateau equation were 87.1 (r^2 = 0.98) for DCS-9 and 72.5 (r^2 = 0.79) kg K_2O/ha for DCH-32. Castor seed yield responses to K fertilization up to 20 kg K_2O/ha were reported earlier under K stress conditions (Murthy and Muralidharudu, 2003).

Cationic nutrient content and uptake: Influence of K levels on K, Ca, Mg, Fe, Zn, Mn and Cu contents and uptake by the castor seeds was shown in Table 1. These cationic nutrient contents in the seed did not show any significant variation due to K fertilization in both the castor cultivars, DCS-9 and DCH-32. However, the nutrient contents in seeds were relatively higher than in control and followed the order K > Mg > Ca > Fe > Zn > Cu > Mn irrespective of cultivar. Uptake of K, Mg, Fe, Mn and Cu by DCS-9 seed varied significantly due to the K application (Table1). Potassium uptake of seed was significant over control at 20 kg K_2O/ha and was at par from 20 to 120 kg K_2O/ha. Magnesium uptake by DCS-9 seed showed a statistically significant variation at 60 kg K_2O/ha. The antagonistic K x Mg effect was observed at higher K levels while low level of K application could not show much antagonistic influence. Further, the movement of K and Mg from source to sink i.e., seed also might have been influenced by K levels. Increasing K supply affects the Mg content of different plant organs to a varying extent (Mengel and Kirkby, 1987). Interestingly, above 60 kg K_2O/ha, the Mg uptake was at par, indicating that increasing levels of K did not influence the Mg uptake by seed further. Similar trends were observed with micronutrients, Fe, Mn and Cu uptake in DCS-9 seed. Zinc uptake in seed varied from 23.5 to 40.4 g/ha, but was statistically non-significant. Relatively higher nutrient content and uptake noticed in DCH-32 hybrid seed could be attributed to vigour, better ability to extract and mobilise nutrients to economic parts. Significant K uptake by the DCH-32 seeds was observed at 60 kg K_2O/ha, while Mg and Cu uptake was influenced significantly at 20 kg K_2O/ha over control.

Nutrient ratios being found as relatively better index to interpret plant analysis data than single nutrient content, cationic nutrient content ratios of soil and seed were computed (Table 2). Available soil cationic nutrient ratios have decreased with increasing levels of K application with few exceptions. Owing to ionic competition and antagonistic effects, the higher levels of K application might have suppressed the other nutrients. Amongst K levels, the seed nutrient ratios have not shown any definite trend in both the castor cultivars although there was a general decrease in ratio at 20 kg K_2O/ha over control. Growth factors (nutrients) interact together within plants, in ways that influence their effectiveness.

Internal nutrient ratio requirement: The "internal nutrient requirement" is the concentration of a nutrient in particular plant tissue associated with 95% of the estimated highest yield attainable when that nutrient, the primary limiting nutrient, is just adequately supplied for nutritional purposes (Fox *et al.*, 1986). Rashid and Fox (1992) evaluated internal zinc requirements of grain crops by seed analysis using boundary line technique. In the present investigation, the nutrient ratios were considered at 94% of the estimated highest castor seed yields and reported (Table 2, Fig. 1 and 2). The nutrient ratios, Ca: K, Mg: K, Fe: K, Zn: K, Mn: K and Cu: K associated with 94% of relative yield of castor DCS-9 are 0.049, 0.495, 0.050, 0.0057, 0.0024 and 0.0034 respectively. These values are considered as "internal nutrient ratio requirement" (INR) expected in DCS-9 seed under K fertilization. Similarly, the INR for castor hybrid, DCH-32 can be perceived (Table 2). These INR values are useful guidelines for assessing plant nutrition. Values observed above and below these may be due to the unknown source-sink relationships luxury consumption of nutrients and Steenbjerg (1951) effects. Boundary line approach is suggested superior to traditional regression analysis when the datum is influenced by unknown and uncontrolled factors (Rashid and Fox, 1992).

Soil nutrient ratios: Soil nutrient ratios have correlated significantly and negatively with the seed yields for both the castor cultivars, which mean lower the soil nutrient ratio higher the seed yields (Table 3). An optimum soil nutrient cation ratio necessary to achieve higher castor seed yields of DCS-9 and DCH-32 at 45th day was determined with quadratic equation. The optimum soil Ca+Mg: K, Fe: K, Zn: K, Mn: K and Cu: K ratios for DCS-9 were 0.074, 0.033, 0.0016, 0.081 and 0.0087 and for DCH-32 0.057, 0.069, 0.020, 0.011, 0.0084, respectively.

Thus, the present study showed that K has a significant influence on seed yields of both the castor variety DCS-9 and hybrid DCH-32 at 87 and 72 kg K_2O/ha respectively in red sandy loam soil under rainfed conditions. Cationic nutrient content and uptake in seeds of both the castor cultivars have varied by K fertilization. The INR established for seeds provided an initial guideline of these limits.

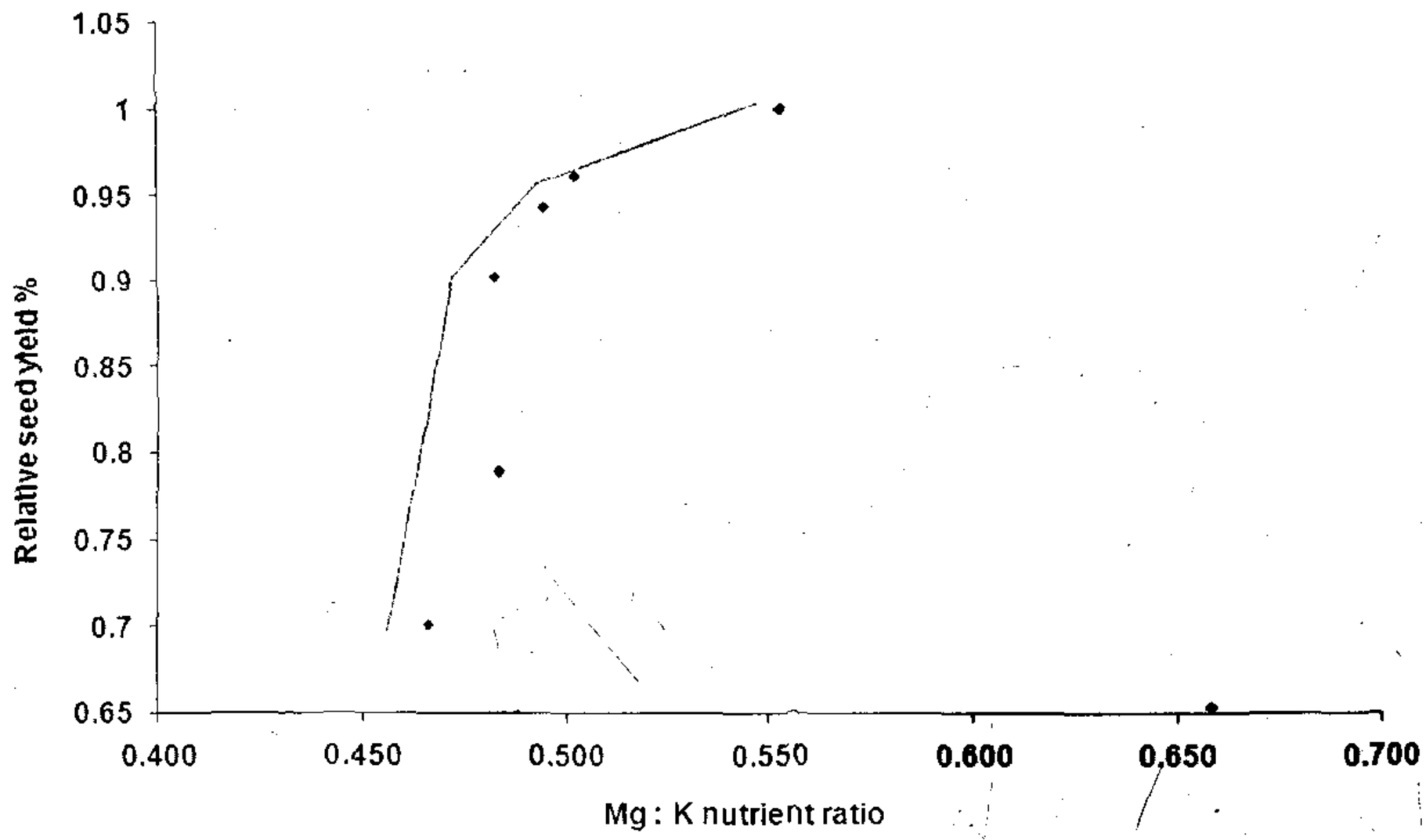

Fig. 1. Relationship between Mg:K nutrient ratio and seed yield of castor variety (DCS-9)

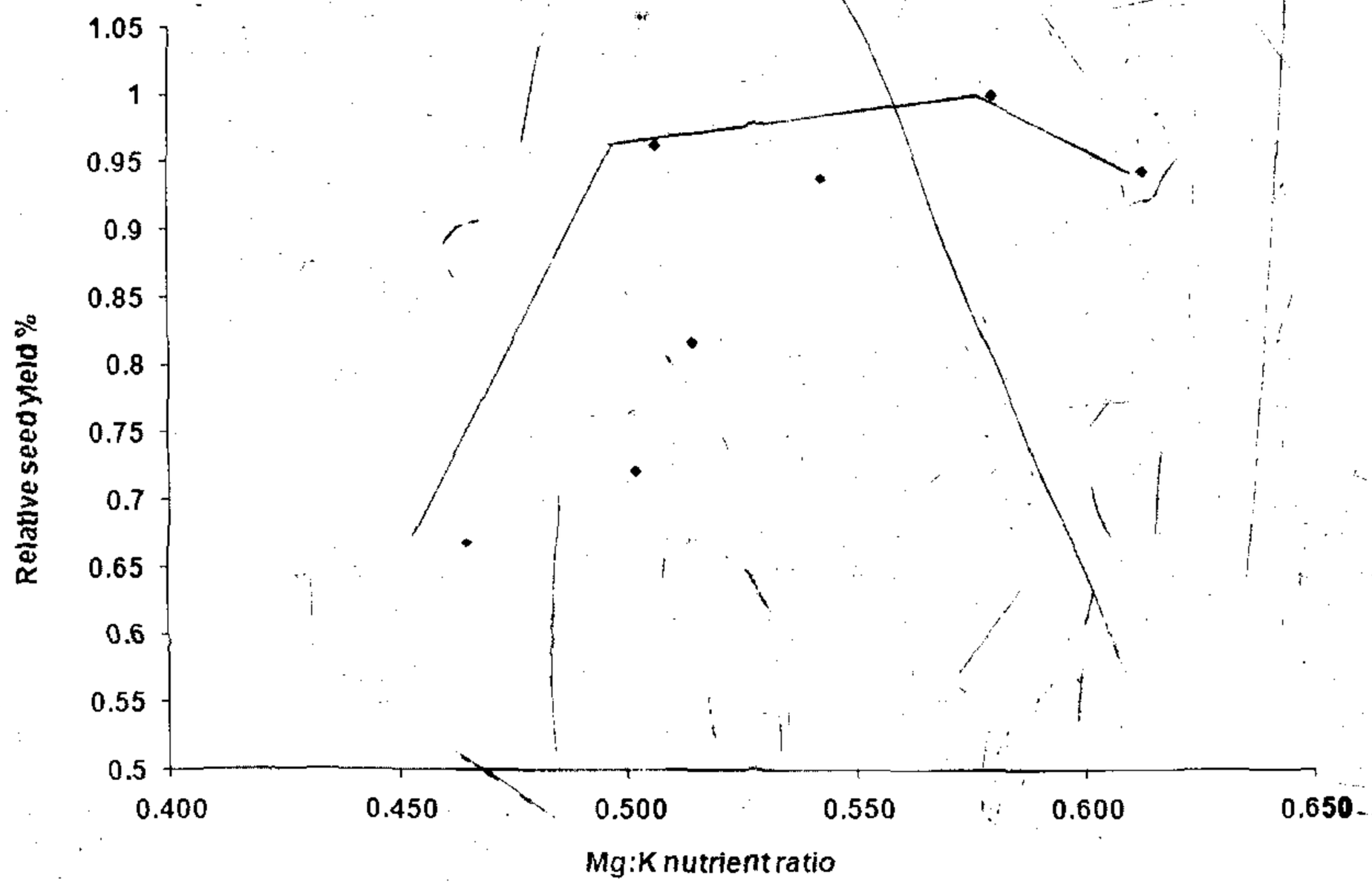

Fig. 2. Relationship between Mg:K nutrient ratio and seed yield of castor hybrid (DCH-32)

Table 1 Influence of potassium levels (kg/ha) on potassium, secondary and micronutrient cation i.e., Ca, Mg, Fe, Zn, Mn and Cu content (mg/kg) and uptake (g/ha) of castor seeds

K_2O levels (kg/ha)	K	Ca	Mg	Fe	Zn	Mn	Cu	K	Ca	Mg	Fe	Zn	Mn	Cu	Total seed yield (kg/ha)
	Content (mg/kg)							Uptake (g/ha)							
							DCS-9								
0	3127.6	199.3	2058.1	182.4	27.5	9.7	15.3	2724.8	170.0	1753.6	155.4	23.5	8.3	13.0	852.2
20	4770.9	363.8	2222.2	242.9	30.9	11.9	15.2	4510.5	335.1	2035.5	222.6	28.4	10.9	13.9	914.4
40	4320.3	292.0	2086.6	207.9	29.4	11.3	14.2	5336.1	298.4	2152.5	213.9	30.3	11.6	14.7	1030.0
60	4724.5	352.8	2278.7	244.5	32.1	11.3	15.9	5020.4	414.5	2681.1	287.3	37.7	13.3	18.7	1176.7
80	4260.7	208.3	2107.4	214.4	24.5	10.1	14.7	5231.7	256.1	2590.1	263.5	30.1	12.5	18.0	1228.9
100	3982.4	286.5	2202.9	274.2	31.0	13.5	15.9	4993.3	373.9	2873.2	357.6	40.4	17.6	20.7	1304.4
120	4167.9	289.8	2094.3	189.0	31.1	9.3	16.4	5419.7	365.9	2628.7	236.9	38.9	11.7	20.5	1253.3
SEm±	342.0	72.0	126.2	28.9	3.0	1.3	0.6	542.5	78.9	166.1	32.6	3.6	1.6	0.8	10.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	1672.1	NS	512.2	100.5	NS	4.9	2.5	33.0
							DCH-32								
0	4035.4	277.4	1875.7	239.8	25.4	8.0	23.2	3438.5	241.3	1624.9	208.7	22.0	6.9	20.3	871.1
20	5029.3	564.9	2523.3	277.5	43.1	12.6	23.5	4622.8	534.1	2387.2	259.0	41.0	11.9	22.3	940.0
40	4313.7	408.7	2341.6	297.7	36.7	12.1	22.7	4455.2	513.5	2837.8	358.0	44.2	14.6	27.6	1222.2
60	4154.7	496.8	2136.8	257.7	32.9	10.8	22.5	4887.7	529.6	2272.5	274.0	34.9	11.4	23.8	1064.4
80	4035.4	338.3	2472.7	289.4	37.9	12.0	24.5	4959.1	416.4	3040.6	357.5	46.7	14.9	29.9	1228.9
100	4439.6	504.7	2248.1	288.6	37.7	13.3	23.7	5792.9	640.1	2814.1	365.4	47.7	16.8	29.8	1253.3
120	4028.8	435.6	2338.0	253.1	39.1	11.9	25.2	5050.8	582.9	3057.9	333.8	52.0	15.9	32.9	1302.2
SEm±	326.3	70.2	169.0	30.7	5.4	1.7	0.8	345.1	108.3	249.3	43.6	7.6	2.3	2.0	15.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	1063.7	NS	768.5	NS	NS	NS	6.3	48.0

Table 2 Influence of potassium levels on secondary and micro nutrient ratios in red soil and castor seeds of DCS-9 and DCH-32

K_2O levels	Ca + Mg: K	Fe: K	Zn: K	Mn: K	Cu: K	Relative yield %	Ca: K	Mg: K	Fe: K	Zn: K	Mn: K	Cu: K
	Soil						Seed					
						DCS-9						
0	0.163	0.022	0.0094	0.051	0.0051	65.3	0.064	0.658	0.058	0.0088	0.0031	0.0049
20	0.143	0.040	0.0077	0.068	0.0074	70.1	0.076	0.466	0.051	0.0065	0.0025	0.0032
40	0.137	0.039	0.0056	0.102	0.0115	79.0	0.068	0.483	0.048	0.0068	0.0026	0.0033
60	0.121	0.019	0.0046	0.057	0.0061	90.2	0.075	0.482	0.052	0.0068	0.0024	0.0034
80	0.105	0.015	0.0037	0.053	0.0046	94.2	0.049	0.495	0.050	0.0057	0.0024	0.0034
100	0.100	0.014	0.0044	0.040	0.0038	100	0.072	0.553	0.069	0.0078	0.0034	0.0040
120	0.053	0.010	0.0018	0.035	0.0032	96.1	0.070	0.502	0.045	0.0075	0.0022	0.0039
						DCH-32						
0	0.169	0.028	0.0060	0.092	0.0071	66.9	0.069	0.465	0.059	0.0063	0.0020	0.0057
20	0.166	0.019	0.0042	0.070	0.0079	72.2	0.112	0.502	0.055	0.0086	0.0025	0.0047
40	0.137	0.018	0.0049	0.075	0.0079	93.9	0.095	0.543	0.069	0.0085	0.0028	0.0053
60	0.121	0.018	0.0058	0.070	0.0063	81.7	0.120	0.514	0.062	0.0079	0.0026	0.0054
80	0.082	0.018	0.0035	0.068	0.0062	94.4	0.084	0.613	0.072	0.0094	0.0030	0.0061
100	0.075	0.014	0.0028	0.053	0.0040	96.2	0.114	0.506	0.065	0.0085	0.0030	0.0053
120	0.060	0.012	0.0025	0.044	0.0035	100	0.108	0.580	0.063	0.0097	0.0030	0.0063

Table 3 Correlation values ® between available soil nutrient ratios and castor seed yield

Available soil nutrient ratio	Seed yield	
	DCS-9	DCH-32
Ca+Mg: K	-0.841**	-0.889**
Fe: K	-0.713**	-0.852**
Zn: K	-0.912**	-0.741**
Mn: K	-0.472*	-0.778**
Cu: K	-0.494*	-0.643**

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

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Nutrient requirements of *kharif* castor, *Ricinus communis* L. under irrigated conditions of Uttar Pradesh

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Abstract

Field experiment conducted at Kanpur (UP) during *kharif* 2006-07 and 2007-08 to find out the optimum fertilizer needs of castor under irrigated conditions, revealed that with increase in nitrogen dose, there was significant increase in seed yield upto 80 kg N/ha. Application of 30 kg phosphorus/ha was found optimum. The crop responded to potassium application in the year 2007-08 upto 30 kg K_2O/ha. Application of 80 kg N/ha, 30 kg P_2O_5 and 30 kg K_2O/ha gave maximum net returns and B:C ratio during both the years.

Key words: Castor, irrigated conditions, fertilizer, economics

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop of India which fetches sizeable amount of foreign exchange to the country through export (Reddy *et al.*, 2006). India's share in world's area and production of castor is 68% and 76%, respectively (Reddy *et al.*, 2006). Oilseeds are energy rich crops and require high amount of nutrients for their production. Inadequate or imbalanced supply of nutrients has been identified as one of the critical constraint limiting oilseeds production. Castor is found to respond to major nutrients, more particularly to nitrogen and phosphorus together rather than singly (Patel *et al.*, 2007). Agro-climatic conditions of Uttar Pradesh are quite suitable for castor cultivation. The present study was made to find out the optimum requirement of fertilizers under irrigated conditions of Uttar Pradesh.

Materials and methods

The field experiment was carried out at Oilseeds Research Farm, Kalyanpur, C.S.A. University of Agriculture & Technology, Kanpur during *kharif* 2006-07 and 2007-08 to find out the optimum fertilizer doses (N, P and K) for castor to obtain maximum yield and returns under irrigated conditions of Uttar Pradesh. The soil of the experimental field was sandy loam in texture, with pH 7.8, low in organic carbon (0.43%), low in available phosphorus (11.7 kg/ha) and medium in available potash (150 kg/ha). Treatment combinations consisting of 4 nitrogen levels (0, 40, 80 and 120 kg N/ha), 3 phosphorus levels (0, 30 and 60 kg P_2O_5/ha) and 2 potassium levels (0 and 30 kg K_2O/ha) were laid out in Randomized Block Factorial Design with 3 replications. The fertilizers were applied as per treatment in the form of urea, diammonium phosphate, single super-phosphate and muriate of potash. Half of N with full dose of P and K was applied basal, and the remaining half nitrogen was top dressed in two equal splits at 30 and 45 days after sowing. Seeds were treated with carbendazim @ 1g/kg of seeds to protect from seed borne diseases. Castor crop was sown on 14 July, 2006 and Aug. 10, 2007 using variety Kalpi-6 in 2006 and hybrid GCH-4 in 2007. Seeds were dibbled @ 2 seeds/hill at a depth of 4-5 cm in the rows 90 cm apart keeping 60 cm plant spacing. All the recommended cultural practices and required suitable plant protection measures were adopted to raise a good crop. The crop was harvested in three pickings manually based on physiological maturity of the capsules. The crop received a rainfall of 499.5mm and 525.6mm during crop season in 2006 and 2007, respectively.

Results and discussion

Response to nitrogen: Significant linear enhancement in plant height, number of spikes/plant, spike length, number of capsules/spike and finally seed yield was recorded with increase in nitrogen dose from 0 to 80 kg N/ha. Venugopal *et al.* (2006) also found the highest number of spike/plant, spike length and number of capsules/spike with the application of 80 kg N/ha. Application of 80 kg N/ha remained comparable with 120 kg N/ha, gave significantly higher value of all these growth and yield attributes than 0 and 40 kg N/ha. Similar results were reported by Anonymous, (2008) from Bawal (Haryana). Better nutrition could have resulted in more number of spikes/plant and capsules/spike (Mathuria and Modhwadia, 1993).

Application of 80 kg N/ha produced significantly higher seed yield than no nitrogen and 40 kg N/ha. Venugopal *et al.* (2006), Anonymous (2007) under Jagdalpur (Chhattisgarh) conditions, Anonymous (2008) under Bawal (Haryana) and Hiriyur (Karnataka) agro-climatic conditions reported similar results. Patel *et al.* (1991) and Sardana *et al.* (2008) recorded the response upto 75 kg N/ha. Supply of 40 kg N/ha also achieved significantly higher seed yield than control while no application of nitrogen (control) resulted in significantly lowest seed yield. There was no remarkable variation in seed yield with 80 and 120 kg N/ha

during both the years. Nitrogen application in adequate quantity has promoted the growth and improved yield attributes of castor, resulting in highest seed yield. This confirms the findings of Ganga Saran and Gajendragiri (1987).

Response to phosphorus: Application of phosphorus 30 kg P_2O_5/ha remaining comparable with 60 kg P_2O_5/ha recorded significantly higher seed yield than no phosphorus application. Thus, 30 kg P_2O_5/ha was found optimum. Similar findings were also reported by Anonymous (2007) from Jagdalpur (Chhattisgarh) and Anonymous (2008) from Hiriyur (Karnataka). Patel *et al.* (2007) observed that application of 25 kg P_2O_5/ha gave significantly higher seed yield of castor than no fertilization (control) while application of 40 kg P_2O_5/ha was found optimum for castor production by Sardana *et al.* (2008) under Punjab agro-climatic conditions.

Response to potassium: Castor responded to potassium application only in the year 2007-08, where application of 30 kg K_2O/ha produced significantly taller plants, more number of spikes/plant, longer spikes and more number of capsules/spike than control. Seed yield was also found significantly superior with 30 kg K_2O/ha to no potassium application during the year 2007-08, while no significant response was noticed to application of potash during the year 2006-07. Response of castor upto 30 kg K_2O/ha was also reported by Anonymous (2007) from Jagdalpur (Chhattisgarh), Anonymous (2007) from Bawal (Haryana) and by Anonymous (2008) from Hiriyur (Karnataka) and Bawal (Haryana) did not observe significant response to potassium application in castor.

Thus, application of 80 kg N/ha and 30 kg P_2O_5/ha was found optimum for castor variety, while castor hybrid required 80 kg N/ha, 30 kg P_2O_5/ha and 30 kg K_2O/ha for its optimum yield. Application of 80 kg N/ha, 30 kg P_2O_5/ha and 30 kg K_2O/ha was found optimum under Hiriyur (Karnataka) agro-climatic conditions.

Economics: Economic evaluation of N,P and K combinations showed that application of 80 kg N/ha, 30 kg P_2O_5/ha and 30 kg K_2O/ha resulted in maximum gross returns, net returns and B:C ratio during the year 2007-08, while net returns and B:C ratio were maximum with this N,P and K combination during both the years. The highest net returns accrued with the application of 80 kg N/ha, 30 kg P_2O_5/ha and 30 kg K_2O/ha could be attributed to higher seed yield. Venugopal *et al.* (2006) also reported the highest net returns of castor with 80 kg N/ha. Highest gross returns, net returns and benefit cost ratio were also obtained with the application of 100% N through fertigation in Gujarat in castor (Patel *et al.*, 2006).

Table 1 Effect of N, P, K fertilizers on growth, yield attributes and bean yield of castor

Fertilizers	Plant height (cm)		Spikes/plant		Spike length (cm)		Capsules/spike		Total seed yield (kg/ha)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Nitrogen levels (kg N/ha)										
0	73.3	80.5	3.4	4.3	18.7	57.4	25	67	511	1742
40	103.4	87.3	3.7	4.7	27.1	62.0	38	74	883	2120
80	128.1	92.3	5.0	5.3	35.9	66.6	55	83	1374	2701
120	135.0	92.3	4.9	5.2	35.9	65.4	55	81	1387	2627
SEm±	0.5	0.7	0.1	0.07	0.4	0.7	0.4	0.6	23	36
CD (P=0.05)	1.5	1.9	0.2	0.19	1.0	1.9	1.0	1.8	67	102
Phosphorus levels (kgP2O5/ha)										
0	102.8	85.0	3.8	4.3	26.6	57.4	39	67	856	1763
30	113.5	89.0	4.5	5.2	30.8	66.0	45	81	1117	2623
60	113.6	90.4	4.5	5.1	30.9	65.1	46	79	1142	2505
SEm±	0.4	0.6	0.1	0.06	0.3	0.6	0.3	0.6	20	31
CD (P=0.05)	1.3	1.6	0.2	0.17	0.9	1.6	0.9	1.6	58	89
Potassium levels (kgK2O/ha)										
0	110.0	87.5	4.3	4.7	29.4	60.9	43	73	1032	2146
30	109.9	88.8	4.3	5.1	29.4	64.8	43	79	1045	2449
SEm±	0.4	0.5	0.1	0.05	0.3	0.5	0.3	0.5	17	25
CD (P=0.05)	N.S	1.3	N.S	0.14	N.S	1.3	N.S	1.3	N.S	72

Table 2 Effect of fertilizers on economics of castor production

Treatment	Seed yield (kg/ha)		Gross returns (Rs./ha)		Cost of cultivation (Rs./ha)		Net returns (Rs./ha)		B.C. ratio	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Nitrogen levels (kg/ha)										
0	511	1742	8080	34843	11819	18347	-3739	15496	0.68	1.80
40	883	2120	13937	42400	12102	19698	1835	22702	1.15	2.15
80	1374	2701	21626	54000	12570	20147	9056	33853	1.72	2.68
120	1387	2627	21907	52533	13044	20624	8863	31909	1.68	2.55
Phosphorus levels (kgP2O5/ha)										
0	856	1763	13510	35262	11796	19352	1714	15910	1.15	1.82
30	1117	2623	17629	52462	12390	19952	5239	32510	1.42	2.63
60	1142	2505	18024	50107	12965	20558	5059	29549	1.39	2.44
Potassium levels (kgK2O/ha)										
0	1032	2146	16322	42913	12246	19816	4076	23097	1.33	2.17
30	1045	2449	16453	48975	12521	20092	3932	28883	1.31	2.44

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Cultural and morphological variability in *Alternaria brassicae* isolates of Indian mustard, *Brassica juncea* L. Czern & Coss.

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Abstract

***Alternaria brassicae* is the most virulent on all brassicaceous plants and cause adverse effect on both quality and quantity of the crop. The present investigation was carried out to know the cultural and morphological variability in *Alternaria brassicae* causing *alternaria* blight of oilseeds Brassica. One hundred and five disease samples were collected from 18 districts of Haryana (India) at 20 to 25 km intervals. The spot/lesion size on leaves of the collected samples ranged from 3.0 to 11.5 mm. These samples were isolated and purified by single spore technique to study the morphological, cultural and radial growth behavior at 20 and 25°C. The radial growth varied from 34.6-81.1 mm with creamish, light brown to dark brown in colour and compressed to fluffy mycelial growth. The average conidial length ranged from 117.0 to192.0 µm and breadth from 14.0 to 24.0 µm. The conidial beak length varied from 42.0 to 116.0 µm, number of horizontal/longitudinal septa ranged from 6 to 9 and vertical/transverse septa ranged from 1 to 3 and average distance between two septa have also been determined.**

Key words: *Alternaria brassicae*, morphological variability, cultural variability

Introduction

Alternaria blight caused by *Alternaria brassicae* (Berk) Sacc., is an economically important disease of oilseed brassica in many parts of the world which cause severe losses both in terms of quantity and quality. In India, the yield losses to the extent of 70% have been reported (Chahal, 1986; Saharan, 1991). Out of four species of *Alternaria* known to occur on this crop, *Alternaria brassicae* is more severe one (Verma and Saharan, 1994). Preliminary reports on variability in *Alternaria* species were made from Holland (Van Schreven, 1953) and UK (Mridha, 1983). There are number of reports on the existence of variability in A brassicae in India on the basis of morphology, growth, cultural characteristics and reaction to host differentials. However, complete information is not available on morphological variability of *A. brassicae* isolates collected from Haryana state. Therefore present investigation was undertaken to find out the cultural and morphological variability in *A. brassicae* isolated collected from all over Haryana.

Materials and methods

Alternaria blight infected 105 samples were collected from 18 districts of Haryana at a distance of 20-25 km. The pathogen *A. brassicae* (Berk) Sacc., was isolated from diseased leaves as per Dhingra and Sinclair (1985). The fungal colonies showing characteristics of *A. brassicae* was picked up and sub cultured in petri plates containing PDA supplemented with rose Bengal. These plates were incubated in BOD incubator at 25±1°C for 4 to 5 days. Isolates were then purified by single spore technique (Toussoun and Nelson, 1976). Isolates were maintained on PDA slants in a refrigerator at 5°C for further studies. The spot/lesion size on leaves of each collected sample was measured. Cultural characteristics of each isolates such as radial growth at 20 and 25°C, colony colour characteristics and growth behavior was observed. Morphological characteristics of each isolates such as conidia length, breadth, number of septations, beak length and average distance between septum were recorded.

Results and discussion

The collected *Alternaria* blight samples have variation in spot/lesion size and symptoms produced. The spot size varies from 3.0 to 11.5 mm in diameter having light brown to dark brown coloration with less to prominent concentric rings. The sample collected from Yamuna Nagar district have minimum spot size (3.0 mm) having light brown spot with less visible rings. The maximum spot size was observed from Sirsa district i.e., 11.5 mm with medium to large dark brown spots with well developed concentric rings (Table 1) The cultural characteristics such as growth behavior and colony character were studied at 20 and 25°C.

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Table 1 Symptoms and spot size of *Alternaria* samples collected from different districts of Haryana (India)

District	Avg. Spot size (mm)	Symptoms
Jind	7.8	Dark brown irregular shape spot with concentric ring
Panipat	5.4	Brown spots with yellowish margin
Sonepat	5.1	Brown spot with less visible concentric rings
Fatehabad	3.8	Dark brown spot with yellowish margin
Kurukshetra	4.8	Irregular, brown spots with less visible concentric rings
Karnal	8.1	Light brown spots with whitish margin, less visible concentric rings
Yamuna nagar	3.0	Light brown spots, less visible rings
Hisar	4.8	Dark brown spot with concentric rings
Bhiwani	6.2	Medium light to dark brown spots with concentric rings
Rohtak	5.3	Small greenish brown spots with irregular shape
Jhajjar	9.4	Light brown spots, concentric rings with papery growth
Rewari	5.5	Small dark brown spots with concentric rings
Kaithal	6.5	Light brown spots with yellowish margin
Mahender Garh	7.0	Dark brown spots with well developed concentric rings
Sirsa	11.5	Medium to large dark brown spots with concentric rings
Faridabad	5.5	Dark brown spots
Gurgaon	8.2	Brown spots with concentric rings
Ambala	5.2	Whitish to brown irregular spots

The pure culture of isolates collected from Yamuna Nagar have maximum growth i.e., 73.6 and 81.1 mm both at 20°C and 25°C followed by isolates collected from Hisar with creamy to dark brown colony character. Isolates collected from Bhiwani district had minimum growth i.e., 34.6 and 40.5 mm with dark brown colony characteristics both at 20 and 25°C (Table 3). Morphological observations recorded on each isolate revealed that isolates differed in their conidial size. The range of conidial length varies from 81.0 to 293.5 µm. Isolates collected from Jind have s collected from Rohtak have maximum conidial length. The conidial breadth also ranges from 8.1 to 31.5 µm. The thickest conidium was of Isolate Kurukshetra and thinnest of isolate Sonepat. The horizontal septation varied from 4-12 and vertical from 0 to 5. The septum distance between two septa also showed some variation which ranges from 6.7 to 14.8µm. Some variation also recorded in beak length and width. The average beak length varied from 26.2 to 225.2 µm. The longest beak was of isolate Rohtak and smallest of Ambala. The beak septation no. ranges from 0-9, (Table 2, Fig. 1).

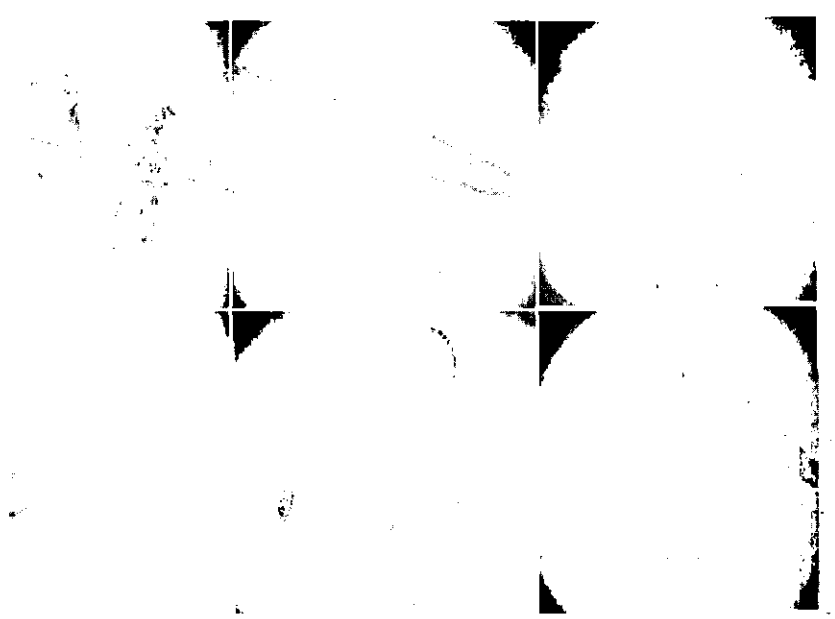

Fig. 1. Morphological variability in *Alternaria brassicae* isolates

Table 2 Morphological variation in conidial size of *Alternaria brassicae* collected from different districts of Haryana (India)

District	Conidial length (µm)	Conidial width (µm)	No. of Septation		Beak		Septum distance (µm)
			Horizontal	Vertical	Length (µm)	Septation No.	
Ambala	118.5(94.5-148.5)	13.8(11.5-19.2)	6.2 (5-7)	0.7(0-3)	41.5(27.0-54.0)	1.8(0-5)	6.7(5.4-9.4)
Jind	117.1(81.0-163.4)	16.2(12.1-20.2	5.6(4-8)	0.8(0-3)	41.8(30.4-51.5)	2.2(1-6)	13.5(12.8-16.2)
Fatehabad	151.2(108.0-192.5)	16.2(13.5-18.9)	5.7(5-8)	1.2(1-5)	54.0(27.0-94.5)	2.1(1-5)	8.1(5.4-10.8)
Gurgaon	191.7(135-233.5)	18.3(14.8-18.3)	7.8(5-12)	1.3(0-4)	54.0(40.5-82.3)	2.7(0-4)	9.4(8.1-13.5)
Y. Nagar	120.2(87.5-154.6)	16.2(14.8-21.6)	5.5(4-7)	1.0(0-4)	42.5(27.0-67.5)	2.2(1-4)	14.8(13.5-16.2)
Faridabad	191.6(121.0.5-293.5)	18.9(14.8-22.95)	8.4(7-12)	1.3(1-3)	60.7(27.0-82.7)	2.1(0-5)	10.8(9.4-13.5)
Panipat	141.7(94.5-192.5)	17.5(13.5-27.0)	6.8(5-9)	1.1(1-4)	52.5(40.5-67.5)	1.6(1-4)	10.8(8.1-12.7)
Karnal	121.5(91.5-148.5)	16.2(13.5-21.6)	5.5(5-8)	0.8(0-3)	67.5(40.5-87.7)	1.2(1-5)	11.7 (8.1-13.5)
Kurukshetra	135.0(94.0-168.5)	21.5(16.5-31.5)	6.8(5-9)	1.0(0-4)	62.5(33.5-81.0)	1.4(1-3)	13.5(9.4-16.2)
Sonepat	148.5(108-186.5)	13.5(8.1-20.2)	5.6(5-8)	0.8(0-3)	54.0(40.5-94.5)	1.2(1-4)	8.1(5.4-13.5)
Hisar	117.3(81.8-161.6)	15.3(9.0-27.1)	6.5(5-9)	1.5(0-3)	47.1(26.2-81.8)	2.2(1-3)	9.4(7.5-12.4)
Bhiwani	137.7(89.9-180.8)	16.8(10.1-25.7)	7.2(6-10)	1.2(0-3)	67.1(45.2-116.1)	4.7(2-8)	10.7(9.2-15.5)
Rohtak	192.5(112.0-290.9)	20.5(9.3-27.2)	6.2(5-9)	2.1(0-4)	116.0(34.3-225.2)	5.6(3-9)	6.9(5.3-10.2)
Jhajjar	165.1(87.8-206.0)	18.2(12.5-25.2)	6.5(4-9)	2.1(0-4)	65.1(35.3-116.1)	1.7(0-3)	12.2(8.7-15.8)
Rewari	157.5(90.9-241.4)	14.4(12.8-18.1)	7.3(5-9)	2.3(0-4)	80.7(35.2-136.3)	3.2(2-5)	13.6(11.8-14.9)
Kaithal	132.9(86.8-207.8)	17.5(16.6-20.8)	7.7(6-11)	2.6(0-5)	42.9(27.2-86.9)	1.8(0-3)	9.8(7.3-12.3)
M. Garh	135.5(90.9-180.8)	17.2(9.9-24.7)	7.4(6-11)	1.2(0-3)	65.2(45.2-118.2)	4.7(2-9)	9.9(7.5-13.4)
Sirsa	146.2(89.9-189.7)	18.1(17.3-21.7)	8.5(7-11)	2.0(0-4)	43.7(31.2-90.9)	2.7(1-5)	11.1(9.8-14.5)

Table 3 Radial growth, colour and growth pattern of different isolates of A. brassicae isolates collected from different districts of Haryana (India) on Indian mustard

District	Radial growth at		Colour	Growth pattern
	20°C	25°C		
Karnal	41.3	45.5	Dark brown	Compressed
Panipat	44.6	48.3	Brownish	Compressed
Fatehabad	38.3	44.6	Light Brown	Compressed
Bhiwani	34.6	40.5	Dark Brown	Compressed
Mahendergarh	42.7	50.0	Brown	Compressed
Rewari	51.3	60.0	Light Brown	Slightly Compressed
Gurgaon	45.5	56.6	Creamy whitish	Fluffy
Faridabad	55.5	66.7	Rough whitish	Fluffy
Hisar	57.6	68.6	Brown to dark brown	Compressed
Kaithal	51.3	56.6	Light brown to rough whitish	Fluffy
Sirsa	37.3	41.3	Light brown	Fluffy
Jind	40.0	46.6	Light brown	Compressed
Rohtak	46.6	55.5	Whitish	Compressed to Fluffy
Ambala	43.3	48.3	Creamy whitish	Fluffy
Jhajjar	46.6	50.0	Creamy white to light brown	Fluffy
Sonepat	53.3	60.0	Whitish	Fluffy
Kurukshetra	45.5	52.5	Light brown	Compressed
Yamuna Nagar	73.6	81.1	White to creamy chocolate	Compressed to Fluffy

Earlier workers also described morphological variation in *A. brassicae* isolates (Saharan and Kadian, 1983). The current results also describe that collected *A. brassicae* isolate have lot of morphological and cultural variation. The conidial length ranges from 81.0 to 293.5 µm and breadth from 8.1 to 31.5 µm. Kumar *et al.* (2003) observed average condial length from 118.62 to 194.52 µm and breadth from 14 to 23µm. They further observed some variation in beak length and number of septation. Mehta *et al.* (2003) categorized *A. Brassicae* isolates in four groups i.e., small (<100µm). Medium (101-150 µm), long (151-200 µm) and very long (>200 µm). These variation in conodinial size may be due to variation in medium concentration and location/site of different field.

The cultural and morphological difference in *A. brassicae* isolates indicates significant variation in the pathogen, it may be attributed due to environmental variation and racial differences.

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Influence of castor, *Ricinus communis* L. as relay crop in controlling root knot disease of groundnut caused by *Meloidogyne arenaria* (Neal) chitwood

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Abstract

Root knot disease of groundnut caused by *Meloidogyne arenaria* is a serious problem in a few farmers' fields of Junagadh and Rajkot districts in Saurashtra region of Gujarat. An experiment was conducted during *kharif* season 2002-03-04 and 2005 in farmers' fields in Junagadh district to find out the effect of relay crops *viz.*, castor (GCH-4), pigeon pea (BDN-2), and sesame (G Til-1) in groundnut in combination with nematicide in managing *M. arenaria*. The data on nematode population, root-knot index and pod equivalent yield data revealed that relay cropping of groundnut with castor (row ratio of 2:1) along with soil application of carbofuran 3G @ 1 kg a.i./ha was highly effective in managing the root knot disease and also in increasing the yield with a CBR of 1:2.35.

Key words: Castor, relay crop, control, root knot nematode, groundnut

Introduction

Groundnut is the most important oilseed crop grown in India, particularly in Gujarat. Plant parasitic nematodes are widespread and important pests of groundnut. Root knot disease caused by *Meloidogyne arenaria* in groundnut has become widespread and causes serious problem at farmers' fields in Junagadh and Rajkot districts in Saurashtra region of Gujarat. The heavily infested plants remain stunted with chlorotic dwarf leaves and profusely galled roots with few lateral roots (Kalaiarasan *et al.*, 2006). Crop losses due to *M. arenaria* on groundnut were about 18% in Saurashtra. Patel *et al.* (1985) observed reduced penetration of *Meloidogyne arenaria* on groundnut with seed treatment of carbofuran and aldicarb as compared to control. Soil application of carbofuran has also been found to reduce the root knots and induce good plant growth. In the past, considerable attention has been paid towards the control of nematode diseases by intercropping/ relay cropping of non-host plants. Gowda and Reddy (1995) studied the management of root knot nematode in tobacco nursery with castor as trap crop along with phenamiphos. The use and practical implication of non-host plants as relay crop has also been reported (Alam *et al.*, 1977). Therefore, the present investigation was carried out to find out the effect of growing relay crops in groundnut growing areas in combination with nematicide on managing *M. arenaria*.

Materials and methods

The experiment was carried out during *kharif* 2002-03-04 and 2005 at farmers' fields located in Junagadh district of Gujarat which were severely infested with *M. arenaria*. Groundnut variety GG-20 was sown with a spacing of 60 cm and three relay crops *viz.*, castor (GCH-4), pigeon pea (BDN-2), and sesame (G Til-1) were sown with a row ratio of 2:1 on different dates using recommended seed rate. Carbofuran 3G @ 1 kg a.i./ha was applied in furrows at the time of sowing. This experiment comprising eight treatments was conducted in a Randomized Block Design with three replications. Initial nematode population/200 cm^3 soil was recorded at sowing and final nematode population/200 cm^3 soil and root-knot index were recorded at 15 days before harvest.

Results and discussion

The initial nematode population (pooled) in the experimental field ranged from 272 to 399 (Table 1). The year-wise data and pooled data (2002-05) on the effect of intercrop on nematode population on groundnut crop indicated that the final nematode population was reduced by 52% when castor was sown as relay crop along with carbofuran followed by sesame and pigeon pea as relay crops (Table 1). The root-knot index was also significantly lowest (1.7) in the treatment where castor was sown as relay crop along with carbofuran followed by pigeon pea along with carbofuran as compared to other treatments (Table 1). Treatment of castor as relay crop along with carbofuran provided significantly higher pod yield followed by pigeon pea as relay crop with carbofuran which did not give any significant difference (Table 1). The highest net realization was obtained in groundnut + castor + carbofuran treatment followed by groundnut + pigeon pea + carbofuran with CBR of 1:2.35 and 1: 2.14, respectively.

Therefore, it is concluded that relay cropping of groundnut with castor (row ratio of 2:1) along with soil application of carbofuran 3G @ 1 kg a.i./ha was highly effective in managing nematode population and the root knot

nematode disease and also increasing the yield (CBR 1:2.35). The present investigations are in agreement with the earlier reports that better plant growth and reduction in root knot index and nematode population in tobacco intercropped with castor and phenamiphos (Dhanger *et al.*, 2002). Gowda *et al.*, (1995) also reported that castor caused maximum trapping of root knot nematodes. Control of *M. incognita* through cropping pattern was also reported by Castillo *et al.*, (1975). Intercropping with marigold resulted in decrease in the number of plant parasitic nematodes on chilli, eggplant, cabbage, cauliflower and tomato (Alam *et al.*, 1977).

It is therefore apparent that growing castor as relay crop followed by application of carbofuran 3G @ 1 kg a.i./ha is more effective, economical and eco-friendly as compared to other treatments.

Table 1 Effect of different relay crops/nematicide on nematode population, root knot index and groundnut pod equivalent yield

Treatment	Initial nematode population/200cm³ soil (Pooled mean of 2002- 05)	Final nematode population/ 200cm³ soil (Pooled mean of 2002- 05)	Root knot index (1- 5) (Pooled mean of 2002- 05)	Pod equivalent yield (kg/ha) (Pooled mean of 2002- 05)	C B R
G'nut + Castor + Carbofuran @ 1 kg a.i./ha as furrow	272	131	1.72	2374	1:2.35
G'nut + Castor	308	315	2.81	1881	1:2.10
G'nut + Sesame+ Carbofuran @ 1 kg a.i./ha as furrow	288	159	2.84	1652	1:1.92
G'nut +Sesame	335	434	3.68	1279	1:1.76
G'nut + Pigeon pea+ Carbofuran @ 1 kg a.i./ha as furrow	292	179	2.54	2212	1:2.14
G'nut + Pigeon pea	346	432	3.53	1899	1:2.15
G'nut + Carbofuran @ 1 kg a.i./ha as furrow	310	213	2.88	1856	1:1.89
G'nut alone	399	571	4.52	1485	1:1.74
SEm ±	25.6	20.8	0.19	149.7	
CD (P=0.05)	75.5	61.2	0.57	440.4	
CV (%)	5.2	10.3	16.2	7.6	
Pooled:					
Year SEm ±	18.1	14.7	0.1	105.8	
CD (P=0.05)	53.4	43.3	NS	311.4	
Y x T SEm ±	9.5	18.1	0.3	80.2	
CD (P=0.05)	27.1	51.4	0.8	227.2	

G'nut = Groundnut

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Productivity potentials and profitability of non-monetary, low-cost and cost-effective oilseeds production technologies

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Abstract

Annual oilseeds support the livelihood earnings of 14 million farmers, majority of them are small and marginal in the arid and semi-arid eco-systems of the country, while one million are involved in processing of oilseeds and oils. The annual oilseed production of the country is faced with high degree of variation, as nearly 76% of the oilseeds area is under rainfed conditions and therefore subjected to uncertainties of moisture availability. Low relative comparative advantage, lower productivity and rainfed prone nature of oilseeds crops and the alarming increase in domestic oil demand, thrust upon the delineation of non-monetary, low-cost and cost-effective oilseeds production technologies for popularization among the oilseed growers. The delineation was done through expost-facto analysis on secondary data pertaining to frontline demonstrations (FLDs) in annual oilseed crops conducted under Technology Mission on Oilseeds (TMOP) and Integrated Scheme on Oilseeds, Pulses, Oilpalm and Maize (ISOPOM). The non-monetary technologies demonstrated through frontline demonstrations, resulted in seed yield increase, ranging from 19 to 50% whereas, the low-cost technologies from 22 to 24%. The demonstration of cost-effective technologies resulted in seed yield increase ranging from 9 to 63%. In the present scenario of oilseeds cultivation in the country, popularization of these proven non-monetary, low-cost and cost-effective oilseeds production technologies to the resource poor oilseed growers, will help them to get remunerative and sustainable yield as well as economic returns.

Key words: Non-monetary, low-cost and cost-effective oilseed technologies, productivity potentials and profitability

Introduction

Nine annual oilseeds crops are being cultivated in 26.51 million ha in India, with the production of 24.29 million tonnes and the productivity of 916 kg/ha (2006-07). India accounts for 15.6, 9.2, 6.8, 5.9, 6.1, 9.0 and 9.3% of world's oilseed area, production, oil meal production, oil meal export, vegetable oil export, vegetable oil import and edible oil consumption. About 12-13% of dietary energy to human beings is supplied by oilseeds. Among the annual oilseeds grown in the country, groundnut, rapeseed-mustard and soybean account for nearly 78% of the oilseed area and 87% of the production. Madhya Pradesh, Gujarat, Rajasthan, Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Uttar Pradesh account for nearly 90 and 92% of oilseeds area and production of the country (Hegde, 2007).

Rationale behind delineation of non-monetary, low-cost and cost-effective oilseeds production technologies

- Annual oilseeds support the livelihood earnings of small and marginal farmers of arid and semi-arid eco-systems of the country. It is estimated that 14 million farmers are involved in oilseed cultivation, while one million persons are involved in processing of oilseeds and oils (Hegde and Venkattakumar, 2007).

  The annual oilseed production of the country is faced with high degree of variation, as nearly 76% of the oilseeds area is under rainfed conditions and therefore subjected to uncertainties of moisture availability.

  The country's minimum support price (MSP) programme that has often favoured production of crops that compete with oilseeds for area. Hence, only by popularizing non-monetary, low-cost and cost-effective oilseeds production technologies among the resource-poor farmers, oilseeds can sustain their competition with the competing crops.

  The continuous cultivation of oilseed crops without proper crop rotation has led to depletion of soil nutrients as well as increase in pest and disease incidence causing upto 40% yield loss (Gowda *et al.*, 2007). This implies the need for use of cost-effective oilseeds-based cropping sequences and intercropping systems.

  Oilseed crops are prone to damage by more than 64 major diseases. For as many as 26 pests in different

crops, no resistant source is available, vulnerability of majority of the cultivars of oilseed crops to insect pests and diseases continues to be one of the major factors responsible for the lower productivity and wider fluctuations in production. (Rabindra *et al.*, 2007). Thus, the need for use of low-cost and cost-effective integrated pest management practices in oilseeds cultivation is significantly important.

Specific attention needs to be given to harness the residual effects of fertilizers containing P, K and S. Sound fertilizer management for intercropping systems involving oilseeds which can meet the nutrient needs of both main and intercrop will go a long way in enhancing the productivity of the system.

Population growth, rising standard of living, aberrant weather for few years in succession and liberalization of export-import policy are the causes for rapid surge in imports (Rao, 2007). The relative advantage is less in case of oilseeds and oils than other food crops. Over the last one decade, the irrigation coverage merely increased by 4% from 23 to 27%.

To obtain the realistic assessment of potential of newly generated oilseed technologies through FLDs, the following thrust areas need to be emphasized while implementing (Rai, 2002): Cropping system demonstrations *viz*, relay, sequential and intercropping systems; maximizing returns per unit area, time and input; cluster area approach; narrowing down the various levels of gaps through efficient resource use management and effective integration of all the research and development agencies that are involved in the development of a particular oilseed crop in a given locality.

As per the data pertaining to the FLDs conducted during 1996-97 to 2006-07 and the national average yield of oilseeds for 2006-07, it was estimated that 227.76 lakh tonnes of additional production could be achieved, apart from 238.84 lakh tonnes of actual production (total could be 466.60 lakh tonnes), if the reservoir of oilseed production projected through FLDs, was utilized through complete adoption of improved technologies advocated for oilseed cultivation. The yield gap was 208% for groundnut and 44, 196, 110, 58, 89, 186, 100 and 148% for rapeseed-mustard, sunflower, safflower, soybean, sesame, niger, castor and linseed respectively. The above-mentioned data suggests the need for popularization of improved oilseed production technologies for use by the oilseed growers.

There is a potential to increase production of oilseeds by using best production practices and right combination of inputs at right time (Kumar and Chauhan, 2007).

The recent demand projections made by Rabo bank for Department of Agriculture and Cooperation (DAC) indicated that the edible oil demand might rise up to 14.8, 18.3 and 21.8 million tones by 2010, 2015 and 2020 respectively. This means, the present level of oilseed production of the country needs to be increased by three times to meet out the projected demand for edible oil for which popularization and use of improved oilseed production technologies is a pre-requisite.

The above points reinforce the necessity for delineation of non-monetary, low-cost and cost-effective oilseeds production technologies and in turn effective transfer of these technologies to the oilseed growers for adoption under real farm situations.

Materials and methods

TMOP and ISOPOM: The Technology Mission on Oilseeds (TMO) launched by Government of India (GOI) in 1986, had a significant impact on overall production of oilseeds. To meet out the challenges that posed through huge demand for vegetable oils in the country, the DAC started implementing Integrated Scheme on Oilseeds, Pulses, Oilpalm and Maize (ISOPOM) to promote crop diversification and to provide focused approach to the oilseed development programmes from April 2004 onwards. In both the schemes, FLDs in oilseeds have been a major mode of transfer of technology effort to prove the improved oilseed production technology under real farm conditions. The delineation of non-monetary, low-cost and cost-effective oilseeds production technologies was done through expost-facto analysis on secondary data FLDs in oilseeds conducted. For this purpose the Annual reports on 'Frontline Demonstrations of Oilseeds' for the period of 1996-97 to 2006-07 were utilized (DOR, 2006a, DOR, 2006b, DOR, 2006c and DOR, 2007).

Operationalization of concepts used in the study

Non-monetary oilseed production technologies: The technologies classified under this category need right decision-making (psychomotor) behaviour of the oilseeds growers for adoption. The intelligence on oilseeds production accumulated based on the past experience and awareness, knowledge on improved technological recommendations, *is needed to be utilized by the farmers* in adopting such oilseeds technologies.

Low-cost oilseed production technologies: The oilseed production technologies with low and minimum cost to be spent apart from the usual cost of cultivation, but results in considerable additional yield and economic benefits are included under this category.

Cost-effective production technologies: The oilseeds production technologies to be adopted by spending considerable cost, but result in sustainable yield and economic returns of the oilseed crops, are operationalized as cost-effective technologies.

Results and discussion

Impact of non-monetary oilseed production technologies

Adoption of recommended spacing: Adoption of recommended spacing between plants and rows, resulted in 5 and 15% seed yield increase under irrigated and rainfed conditions of castor respectively, with corresponding additional net returns of Rs.268 and 1845/ha (Table 1). The same technology in linseed, gave 65% seed yield increase and additional net returns of Rs.2075/ha. In sunflower, the technology gave around 25% seed yield increase under both irrigated and rainfed conditions, whereas, the corresponding additional net returns was Rs.3733 and 4760/ha. Under rainfed conditions, adoption of recommended spacing resulted in 11 and 25% seed/ pod yield increase for sesame and groundnut resulting in additional net returns of Rs.1551 and 5923/ha respectively. As a whole for oilseeds, the technology gave 19% seed yield increase and Rs. 2853/ha additional net returns. The B:C ratio was 2.8 and 2.5 with IT and FP plots respectively (Table 4).

Adoption of right method of sowing: Adoption of the recommended method of sowing in sunflower gave 51% seed yield increase under irrigated conditions, whereas 25% under rainfed conditions. The additional net returns obtained was Rs.5254 and 3435/ha respectively for irrigated and rainfed conditions (Table 1). The seed/ pod yield increase as a result of adoption of this technology over the local practice was four times in irrigated than rainfed conditions in safflower and 2.5 times in groundnut. The seed yield increase was 90 and 76% for sesame and niger under rainfed conditions with corresponding additional net returns of Rs. 1408 and 2184/ha. For rapeseed-mustard, the seed yield increase was 36% with Rs.4072/ha additional net returns under irrigated conditions. As an overall impact, the seed yield increase was observed as 39% with Rs.3286/ha additional net returns. The B:C ratio was 2.4 and 2.1 with IT and FP plots respectively (Table 4).

Adoption of timely sowing: Adoption of timely of sowing resulted in 44 and 55% seed yield increase for sunflower and rapeseed-mustard respectively under irrigated conditions, with accrued additional net returns of Rs.3997 and 1061/ha respectively (Table 1). Under rainfed conditions, the same technology resulted in 182 and 13% seed/ pod yield increase for niger and groundnut with Rs.3150 and 2889/ha additional net returns. The overall impact was 36% for seed yield increase and Rs.4190/ha for additional net returns (Table 4). The B:C ratio was 2.5 and 2.3 with IT and FP plots respectively.

Adoption of right method of fertilizer application: Adoption of right method of fertilizer application, under rainfed conditions, gave 42% seed yield increase with Rs.2771/ ha additional net returns for rapeseed-mustard. The B:C ratio was 3.6 and 2.5 with IT and FP plots respectively (Table 1 and 5).

Adoption of timely weeding: There was 39% seed yield increase in rapeseed-mustard under rainfed conditions (Table 1 and 5), when timely weeding was adopted under real farm conditions.

Selecting oilseed crops to competing crops: Selecting castor instead of maize, cotton and sorghum gave 104, 87 and 5% seed yield increase under rainfed conditions (Table 1). The corresponding additional net returns was 3121, 8237 and 5674/ha. Though tomato gave 21% seed yield equivalent increase than castor, there was Rs.675/ha additional net returns from castor, sine the labour requirement of castor is lower than that of tomato. Under irrigated conditions, sunflower was proved to be superior to finger millet by 86% in seed yield equivalent and Rs.12340/ha in net returns. As a whole, the above-mentioned oilseed crops proved 50% seed yield equivalent increase and Rs.6009/ha additional net returns to competing crops. The B:C ratio was 3.0 and 2.1 with IT and FP plots respectively (Table 4).

Adoption of improved varieties and hybrids of oilseeds: Choice of improved varieties of groundnut to locals and existing ones, gave 25% pod yield increase both under rainfed and irrigated conditions. In rapeseed-mustard, the technology gave seed yield increase to the tune of 58% under irrigated conditions with Rs.4171/ha additional net returns. Improved dual-purpose linseed variety gave 68% seed yield enhancement and Rs.15453/ha additional net returns. Improved niger variety resulted in 120% seed yield increase and Rs.2383/ha additional net returns. Similarly, improved varieties gave seed yield increase to the tune of 27 and 45% under rainfed conditions in soybean and castor respectively, with corresponding additional net returns of Rs.2960 and 5340/ha (Table 1). Overall, improved varieties/ hybrids of oilseeds resulted in 36% seed yield increase, with Rs.3645/ha additional net returns. The B:C ratio was 2.4 and 2.1 with IT and FP plots respectively (Table 4).

Adoption of recommended crop sequence: Adoption of recommended crop sequence resulted in 83 and 62% seed yield increase in linseed under rainfed and irrigated conditions respectively (Table 1). The additional net returns obtained was Rs.4184 and Rs.3443/ha, under rainfed and irrigated conditions respectively. In castor, it resulted in 33% seed yield increase with Rs. 3900/ha additional net returns under rainfed conditions and 11% seed yield increase and Rs. 2004/ ha additional net returns, under irrigated conditions. In case of rapeseed-mustard, the seed yield increase as result of adoption of recommended crop sequence was 46 and 87% in irrigated and rainfed conditions respectively, with corresponding additional net returns of Rs.4955 and 6749/ha. In sunflower, under irrigated conditions, the technology resulted in 19% seed yield increase with

Rs.3491/ha additional net returns. The technology as a whole, gave 37% seed yield increase and Rs.5896/ha additional net returns. The B:C ratio was 2.0 and 1.8 with IT and FP plots respectively (Table 4).

Impact of low-cost oilseed production technologies

Adoption of seed treatment practice: Adoption of seed treatment with chemicals and/or biofertilizers for pest management and nutrient supplement, resulted in 10% seed yield increase both under rainfed and irrigated conditions in sunflower, with additional net returns of Rs.1525/ ha. (Table 2). In safflower, the technology gave 12% seed yield increase and Rs.413/ha additional net returns under rainfed conditions. Under similar conditions in rapeseed-mustard, it gave 24% seed yield increase with Rs.2550/ha additional net returns. In groundnut, under irrigated conditions, this technology gave 44% pod yield increase and Rs.1957/ha additional net returns. This technology gave 24% seed yield increase and Rs.1083/ ha additional net returns as an overall impact (Table 4). The B:C ratio was 2.3 and 2.6 with IT and FP plots respectively.

Adoption of thinning: Thinning excess plant population to maintain the recommended plant stand, resulted in seed yield increase to the tune of 26 and 32% in sunflower and safflower under irrigated conditions, with corresponding additional net returns of Rs.3576 and 4624/ha respectively (Table 2). In rapeseed-mustard under irrigated conditions, this technology gave 16% seed yield increase, with Rs.2258/ha additional net returns. Overall, this technology gave 24% seed yield increase and Rs.3238/ha additional net returns (Table 4). The B:C ratio was 2.6 and 2.3 with IT and FP plots respectively.

Use of biofertilizers: *Application of biofertilizers, as a* nutrient supplement, resulted in 9, 24 and 40% seed yield increase in sunflower, safflower and niger with Rs.1101, 1871 and 537/ha additional net returns respectively (Table 2). Under irrigated conditions, this technology gave seed/ pod yield increase to the tune of 44% for groundnut and 6% for rapeseed-mustard with corresponding additional net returns of Rs.1957 and 1883/ha. Overall, this technology gave 22% seed yield increase with Rs.1925/ha additional net returns. The B:C ratio was 2.2 and 2.1 with IT and FP plots respectively (Table 4).

Application of gypsum: Application of gypsum in groundnut to increase pod yield and oil content of the crop and physio-chemical properties of the soil, resulted in 25% pod yield increase and Rs.342/ha additional net returns under rainfed conditions (Table 2 and 5). The B:C ratio was 1.5 and 1.6 with IT and FP plots respectively.

Application of sulphur: Application of sulphur to increase oil content in rapeseed-mustard resulted in 11% seed yield increase and Rs.3277/ha additional net returns under rainfed conditions (Table 2 and 5). The B:C ratio was 2.6 and 2.4 with IT and FP plots respectively.

Spraying of cycocel: Spraying cycocel as a growth regulator for safflower resulted in seed yield increase to the tune of 33% under irrigated conditions with Rs.5030/ ha additional net returns (Table 2). Overall, the seed yield increase was 24% and the additional net returns was Rs.2778/ha (Table 4). The B:C ratio was 2.4 and 2.2 with IT and FP plots respectively.

Application of sulphur+boron: Sulphur+boron application to improve the oil content in sunflower resulted in 34% seed yield increase and Rs.8358/ha additional net returns under rainfed conditions (Table 2 and 5).

Impact of cost-effective oilseed production technologies

Integrated nutrient management (INM): Adoption of INM practices to improve the productivity of the crop as well as soil fertility in a sustained manner resulted in seed/ pod yield increase to the tune of 22 and 19% in groundnut and rapeseed-mustard under irrigated conditions. The corresponding additional net returns was Rs.4806/ha for groundnut (Table 3). Overall, the technology gave 20% seed yield increase and Rs.1577/ha additional net returns (Table 4). The B:C ratio was 2.2 and 2.4 with IT and FP plots respectively.

Integrated weed management (IWM): *IWM practices to* manage the weeds in a sustained and cost-effective manner resulted in pod yield increase of 10% in groundnut under irrigated conditions. The corresponding additional net returns was Rs.3984/ha (Table 3 and 5). The B:C ratio was 2.6 and 2.4 with IT and FP plots respectively.

Integrated water management: Integrated water management practices to meet the minimal water requirement of the crop with higher use efficiency and ensuring the sustained availability of water to the crop eco-system gave 9% pod yield increase and Rs.2481/ ha additional net returns in groundnut (Table 3 and 5). The B:C ratio was 2.3 and 2.2 with IT and FP plots respectively.

Integrated pest management (IPM): IPM practices to ensure the arrest of resilience of insect pests of crops through integrated management practices and ecological balance in pest management in groundnut gave pod yield increase to the tune of 18% with Rs. 3354/ ha additional net returns under rainfed conditions, whereas, 19% seed yield increase for rapeseed-mustard under irrigated conditions (Table 3). Overall, the seed yield increase was 17% and additional net returns was Rs.35771/ha (Table 4). The B:C ratio was 2.1 and 2.0 with IT and FP plots respectively.

Polythene mulching: Polythene mulching for arresting the weed population and conserving the soil moisture by preventing evaporation losses in groundnut gave pod yield increase to the tune of 51% with Rs.15643/ha additional net returns (Table 3 and 5). The B:C ratio was 2.6 and 2.2 with IT and FP plots respectively.

Table 1 Impact of non-monetary oilseeds production technologies*

Crop	Situation	No. of demos.	Mean seed yield (kg/ha)		% increase in yield	Cost of cultivation (Rs./ha)		Gross returns (Rs./ha)		Addl.net returns (Rs./ha)	B:C ratio	
			IT	FP		IT	FP	IT	FP		IT	FP
Adoption of Recommended Spacing												
Castor	I	3	2332	2213	5	7056	7355	29375	29407	268	4.0	4.0
	R	6	1696	1474	15	6474	5999	22696	20377	1845	3.8	3.4
Linseed	I	2	576	350	65	3855	3218	6912	4200	2075	2.1	1.3
Sunflower	I	22	1464	1173	25	10194	9556	22170	17799	3733	2.3	1.9
	R	31	1345	1067	26	6710	6253	19661	14444	4760	3.1	2.3
Sesame	R	1	427	385	11	2972	2517	8855	6849	1551	3.5	2.7
Groundnut	R	9	1965	1575	25	12527	11250	31448	24428	5923	2.8	2.2
Adoption of Right Method of Sowing												
Sunflower	I	2	1378	913	51	5470	4344	17379	10999	5254	4.0	2.5
	R	5	1108	885	25	5604	5370	16053	12396	3435	3.0	2.3
Safflower	I	1	2500	2025	23	5505	6415	35000	28350	7560	5.5	4.4
	R	5	806	762	6	6204	4641	8618	7914	-859	1.9	1.7
Sesame	R	2	275	145	90	1960	1448	3880	1960	1408	2.7	1.4
Groundnut	I	1	2625	2000	31	18062	16340	34725	26687	6316	2.1	1.6
	R	5	550	492	12	7256	6479	9355	8361	217	1.4	1.3
Rapeseed-mustard	I	9	1389	1023	36	9896	8186	22430	16647	4072	2.7	2.0
Niger	R	42	402	228	76	3393	2156	6992	3571	2184	3.2	1.7
Following Timely Sowing												
Sunflower	I	2	1015	703	44	8100	8066	13219	9188	3997	1.6	1.1
Niger	R	104	316	112	182	3440	3017	5389	1817	3150	1.8	0.6
Rapeseed-mustard	I	33	1559	1009	55	6193	5723	20495	13302	1061	3.6	2.3
Groundnut	R	4	1938	1719	13	11436	10950	34137	30762	2889	3.1	2.8
Adoption of Right Method of Fertilizer Application												
Rapeseed-mustard	R	31	936	661	42	4723	3541	12727	8774	2771	3.6	2.5
Adoption of Timely Weeding												
Rapeseed-mustard	R	3	1635	1175	39	-	-	-	-	-	-	-
Selecting Oilseeds to Competing Crops**												
Castor/maize	R	4	2157	1060	104	6608	6013	18404	14688	3121	2.8	2.4
Sunflower/ finger millet	I	10	2260	1215	86	13873	10149	34754	18690	12340	2.5	1.8
Castor/ cotton	R	2	2338	1250	87	6739	8882	31782	25688	8237	4.7	2.9
Castor/ sorghum	R	19	1998	1900	5	5489	5036	14306	8179	5674	2.6	1.6
Castor/ tomato	R	2	688	875	-21	3827	8257	9369	13125	675	2.4	1.6
Adoption of Improved Varieties/ Hybrids												
Groundnut	I	213	2483	1976	26	16911	15255	40564	31973	6934	2.4	2.1
	R	1084	1839	1476	25	15310	13955	34596	27847	5393	2.3	2.0
Rapeseed-mustard	R	71	967	697	39	6187	5704	13120	9009	3628	2.1	1.6
	I	27	555	351	58	8859	6528	16070	9567	4171	1.8	1.5
Sesame	R	136	515	367	40	6440	5344	16431	11414	3920	2.6	2.1
	DP	3	1567	933	68	10470	8456	3350	15583	15453	3.2	1.8
Linseed	I	41	1160	848	37	10852	9269	21400	15794	4022	2.0	1.7
	R	25	634	420	51	4802	4196	12212	8456	3150	2.5	2.0
Niger	R	81	352	160	120	3527	1778	7188	3057	2383	2.0	1.7
Soybean	I	9	460	408	13	2477	2440	19929	17158	2734	8.0	7.0
	R	36	756	594	27	6943	6422	13556	10076	2960	2.0	1.6
Castor	I	105	2618	1970	33	11262	11838	35384	21425	14535	3.1	1.8
	R	208	1393	961	45	8186	6794	27637	20906	5340	3.4	3.1
Safflower	I	12	1386	783	77	6969	5032	20132	11006	7189	2.9	2.2
	R	209	922	719	29	6205	5427	13423	10301	2344	2.2	1.9
Sunflower	I	69	1609	1331	21	8771	8373	25426	21023	4004	2.9	2.5
	R	93	1193	985	21	7469	7389	20294	16708	3506	2.7	2.3
Adoption of Recommended Crop Sequence												
Linseed	R	1	1434	785	83	13400	5870	21527	9813	4184	3.7	1.7
Castor	I	5	1014	625	62	7542	5879	13298	8193	3443	2.3	1.4
	R	1	1600	1200	33	7910	7410	17600	13200	3900	2.4	1.8
Rapeseed-mustard	I	6	2677	2419	11	11586	10307	35178	31896	2004	3.4	3.1
	I	93	1959	1339	46	8996	5713	24725	16488	4955	4.3	2.9
	R	8	1323	707	87	7558	5879	17844	9416	6749	3.0	1.6
Safflower	R	6	1462	1161	26	13160	10451	5938	3434	-205	0.6	0.3
Sunflower	I	11	1446	1213	19	7052	7048	18895	15399	3491	2.7	2.2

IT= Improved technology; FP=Farmers' practice; I=Irrigated; R=Rainfed; DP=Dual purpose;

*-The data pertaining to timely weeding, selecting oilseeds crops to competing crops and selection of improved varieties/ hybrids were of the period from 2002-03 to 2006-07, whereas the remaining data were of the period from 1996-07 to 2006-07; **-expressed in seed yield equivalent

Table 2 Impact of low-cost oilseeds production technologies*

Crop	Situation	No. of demos.	Mean seed yield (kg/ha)		% increase in yield	Cost of cultivation (Rs./ha)		Gross returns (Rs.ha)		Addl net returns (Rs./ha)	B:C ratio	
			IT	FP		IT	FP	IT	FP		IT	FP
					Seed Treatment							
Sunflower	I	4	1187	1079	10	4313	4088	19000	17250	1525	4.6	4.2
Safflower	R	2	811	725	12	6665	4800	14603	12325	413	3.0	2.6
Groundnut	I	3	2333	1625	44	20558	14799	33533	25817	1957	2.3	1.7
Rapeseed-mustard	R	6	968	778	24	3400	3198	14031	11279	2550	4.4	3.5
					Thinning							
Sunflower	I	25	1303	1034	26	8282	7692	19938	15766	3576	2.6	2.0
	R	52	1131	945	20	7357	6919	20277	17209	2629	2.9	2.5
Safflower	I	32	1445	1093	32	7807	7046	21118	15733	4624	3.0	2.2
	R	108	1170	908	29	6402	5855	16219	12573	3099	2.8	2.1
Rapeseed-mustard	I	25	1555	1336	16	7865	7130	21770	18778	2258	3.1	2.6
					Biofertilizer							
Sunflower	R	8	856	783	9	4425	4257	14974	13705	1101	3.5	3.2
Safflower	R	7	867	697	24	4295	3750	11568	9152	1871	3.1	2.4
Niger	R	6	208	149	40	1758	1399	2877	1982	537	2.1	1.4
Groundnut	I	3	2333	1625	44	20558	14799	33533	25817	1957	2.3	1.7
	R	110	1790	1500	19	14926	13108	34591	28570	4203	2.6	2.2
Rapeseed-mustard	I	8	1787	1681	6	15026	15016	35655	33762	1883	2.4	2.2
					Gypsum Application							
Groundnut	R	3	1077	865	25	7691	5788	11405	9160	342	1.5	1.6
					Sulphur Application							
Rapeseed-mustard	R	37	1710	1535	11	11496	10962	29767	25956	3277	2.6	2.4
					Cycocel Spray							
Safflower	I	2	1380	1038	33	6396	5433	24150	18157	5030	3.8	3.3
	R	11	1063	884	20	7933	7138	16387	13565	2027	2.1	1.9
					Sulphur+Borax							
Sunflower	R	10	1441	1073	34	5724	5304	25938	17160	8358	4.5	3.2

IT= Improved technology; FP=Farmers' practice; I=Irrigated; R=Rainfed; *-The data were of the period from1996-07 to 2006-07

Table 3 Impact of cost-effective oilseeds production technologies*

Crop	Situation	No. of demos.	Mean seed yield (kg/ha)		% increase in yield	Cost of cultivation (Rs./ha)		Gross returns (Rs./ha)		Addl.net returns (Rs./ha)	B:C ratio	
			IT	FP		IT	FP	IT	FP		IT	FP
					Integrated Nutrient Management							
Groundnut	I	116	2424	1995	22	17770	15933	40387	33744	4806	2.3	2.1
	R	224	1579	1334	18	13281	11691	30113	24973	3550	2.3	2.1
Rapeseed-mustard	I	5	1737	1470	19	15500	7930	30870	26926	-3626	2.0	3.4
					Integrated Weed Management							
Groundnut	R	14	2216	2023	10	16531	16684	43734	39903	3984	2.6	2.4
					Integrated Water Management							
Groundnut	I	23	1588	1461	9	15105	14913	35024	32350	2481	2.3	2.2
					Integrated Pest Management							
Groundnut	I	42	2439	2138	14	18340	16774	42732	37367	3838	2.3	2.2
	R	106	1632	1380	18	16576	14681	32073	26824	3354	1.9	1.8
Rapeseed-mustard	I	2	1768	1490	19	-	-	-	-	-	-	-
					Integrated Disease Management							
Groundnut	I	30	1528	1135	35	13690	11206	32047	23765	5798	2.3	2.1
	R	119	1677	1354	24	12257	9848	27805	22161	3236	2.3	2.3
Rapeseed-mustard	I	8	1714	1575	9	12688	12375	29137	26912	1913	2.3	2.2
					Oilseed-based Intercropping Systems							
Linseed	I	90	1342	638	110	8945	6277	24399	13131	8600	2.7	2.1
	R	53	1048	566	85	7513	5303	19926	9622	8694	2.7	1.8
Sesame	I	7	549	382	44	3624	2861	17651	11485	5402	4.9	4.0
	R	73	559	362	54	7292	5468	16344	10746	3774	2.2	2.0
Niger	R	22	554	234	137	4898	2694	9765	4050	3511	2.0	1.5
Soybean	R	27	1691	1127	50	7497	5358	21905	14801	4966	2.9	2.8
Castor	R	40	1789	900	99	8429	6186	29480	16791	10446	3.5	2.7
	I	38	2600	1725	51	16101	11318	53440	37162	11495	3.3	3.3
Safflower	R	119	1094	792	38	6208	5593	15230	10805	3810	2.5	1.9
Sunflower	R	61	975	780	25	7992	7382	17698	14122	2966	2.2	1.9
					Polythene Mulching							
Groundnut	I	11	2660	1785	49	18326	14881	47878	32518	11915	2.6	2.2
	R	13	3032	2005	51	20184	16870	56684	37728	15643	2.8	2.2
					Thio urea Application							
Rapeseed-mustard	I	18	1808	1644	10	10677	9944	27551	25146	1673	2.6	2.5

IT=Improved technology; FP=Farmers' practices; I=Irrigated; R=Rainfed; *-The were of the period from 2002-03 to 2006-07

Table 4 Impact of non-monetary, low-cost and cost-effective oilseeds production technologies

Technology	No. of demos.	Mean seed yield (kg/ha)		% increase in yield	Cost of cultivation (Rs./ha)		Gross returns (Rs./ha)		Addl.net returns (Rs./ha)	B:C ratio	
		IT	FP		IT	FP	IT	FP		IT	FP
Non-monetary oilseeds production technologies											
Selecting oilseeds to competing crops*	37	1888	1260	50	7307	7667	21723	16074	6009	3.0	2.1
Choice of improved varieties*	2422	1201	881	36	8332	7306	20042	15371	3645	2.4	2.1
Recommended Spacing	74	1401	1177	19	7113	6593	20160	16786	2853	2.8	2.5
Correct method of sowing	72	1226	941	39	7039	6153	17159	12987	3286	2.4	2.1
Correct time of sowing	143	1207	886	36	7292	6939	18310	13767	4190	2.5	2.3
Correct method of fertilizer application	31	936	661	42	4723	3541	12727	8774	2771	3.6	2.5
Timely weeding*	3	1635	1175	39	-	-	-	-	-	-	-
Adoption of Recommended crop sequence	131	1614	1181	37	9651	7320	19376	13480	5896	2.0	1.8
Low-cost production technologies											
Seed treatment	17	1228	994	24	8168	6095	19049	15893	1083	2.3	2.6
Thinning	242	1321	1063.2	24	7543	6928	19864	16012	3238	2.6	2.3
Biofertilizer application	142	1307	1073	22	10165	8722	22200	18831	1925	2.2	2.1
Application of gypsum in groundnut	3	1077	865	25	7691	5788	11405	9160	342	1.5	1.6
Application of sulphur in rapeseed-mustard*	37	1710	1535	11	11496	10962	29767	25956	3277	2.6	2.4
Application of cycocel in safflower*	13	1142	923	24	7549	6712	18328	14713	2778	2.4	2.2
Application of Sulphur+Borax in sunflower*	10	1441	1073	34	5724	5304	25938	17160	8358	4.5	3.2
Cost-effective production technologies											
Integrated nutrient management*	345	1913	1600	20	15517	11851	33790	28548	1577	2.2	2.4
Integrated weed management*	14	2216	2023	10	16531	16684	43734	39903	3984	2.6	2.4
Integrated water management*	23	1588	1461	9	15105	14913	35024	32350	2481	2.3	2.2
Integrated pest management*	150	1946	1669	17	17458	15728	37403	32096	3577	2.1	2.0
Integrated disease management*	157	1640	1355	21	12878	11143	29663	24279	3648	2.3	2.2
Oilseed-based intercropping systems*	530	1220	751	63**	7850	5844	22584	14272	6306	2.9	2.4
Polythene mulching in groundnut*	11	2660	1785	49	18326	14881	47878	32518	11915	2.6	2.2
Application of thio-urea in rapeseed-mustard*	18	1808	1644	10	10677	9944	27551	25146	1673	2.6	2.5

*-The data pertaining to these technologies were of the period from 2002-03 to 2006-07, whereas the remaining data were of the period from1996-07 to 2006-07; **-Seed equivalent yield

Application of thio-urea: Thio-urea application to improve the oil content of rapeseed-mustard resulted in 10% seed yield increase and Rs.1675/ha additional net returns under irrigated conditions (Table 3 and 5). The B:C ratio was 2.6 and 2.5 with IT and FP plots respectively.

Oilseeds-based intercropping systems: Intercropping systems are recommended with a view to improve the yield and returns per unit area, while helping in efficient and effective use of available space as well as critical inputs of the crops. These practices also help as an insurance against crop failure. Use of linseed-based intercropping systems gave seed equivalent yield increase to the tune of 110%, with Rs.8600/ha additional net returns (Table 3). Sesame-based intercropping systems gave seed equivalent yield increase to the tune of 54%, with Rs.3774/ha additional net returns. Similarly, niger, soybean, safflower, sunflower and castor-based intercropping systems resulted in seed equivalent yield increase of 137, 50, 38, 25 and 99%, under rainfed conditions with corresponding additional net returns of Rs.3511, 4966, 3810, 2966 and 10446/ha. Overall, the oilseeds-based intercropping systems gave 63% seed equivalent yield advantage, with Rs.6306/ha additional net returns (Table 4). The B:C ratio was 2.9 and 2.4 with IT and FP plots respectively.

Conclusion

The non-monetary technologies that just need right decision making (psychomotor) behaviour of the oilseeds growers for adoption, demonstrated through frontline demonstrations, resulted in seed yield increase, ranging from 19 to 50% for adoption of recommended spacing and selecting oilseeds to competing crops respectively. The average cost of these non-monetary technologies was Rs.7351/ha, with a range of Rs.4723 to 9651/ha. The low-cost technologies to be adopted with minimal cost to be spent, which results in considerable additional yield and economic benefits, resulting in seed yield increase ranging from 22 to 24% for biofertilizer application to seed treatment respectively. The average cost of these low-cost technologies was Rs.8334/ha, ranging from Rs.5724 to 11496/ha. The demonstration of cost-effective technologies to be adopted by spending considerable cost, but result in sustainable yield and economic returns of the oilseed crops, resulted in seed yield increase ranging from 9 to 63% for integrated water management to oilseeds-based intercropping systems respectively. The cost of these cost-effective technologies was ranging from Rs.7850 to 17458/ha, with an average of Rs.14293/ha. In the present scenario of oilseeds cultivation in the country, popularization of these proven non-monetary, low-cost and cost-effective oilseeds production technologies among

resource poor oilseed growers, will help them to get remunerative and sustainable yield as well as economic returns, in the backdrop of import of huge quantity of edible oils in the globalized market economy and remote chances for acquiring additional area for cultivation of oilseeds from that of food grains.

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Short communication

Genetic divergence in groundnut, *Arachis hypogaea* L.

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Abstract

D^2-statistics, grouped 80 genotypes of groundnut into 9 clusters. The clustering pattern of the genotypes did not confirm to the geographical distribution. The maximum intercluster distance was observed between clusters I and VIII followed by clusters IV and VIII, clusters III and VIII and clusters II and VIII. The cluster VII showed high mean in respect to pod yield/plant, number of secondary branches/plant, number of aerial pegs/plant, number of kernels/pod, 100-kernel weight and harvest index. The cluster I had desirable value for days to 50% flowering and days to maturity. While higher number of primary branches was found in cluster V. The cluster VII was the best for plant height and biological yield/plant. The cluster IV and III had desirable values for shelling percentage and oil content, respectively. The cluster IX was the best for number of underground pegs/plant. It will be advisable to intercross among the genotypes from clusters I, II, III, IV and VIII for generation of transgressive segregants and wide spectrum genetic variability for improvement of pod yield in groundnut.

Keywords: D^2 statistics, groundnut, diversity

In India groundnut is principal oilseed crop and contributes about 35% of area and 40% of oilseed crops grown in the country. Among the major groundnut growing states Gujarat rank first in production (1.8 million tonnes) and second in area (1.85 million hectares) in the country. Plant breeders are always interested in assessing genetic divergence among the varieties or advance breeding line available with them so as to utilize in directed breeding programme because genetically diverse parents are likely to produce high heterotic effects and the distinctly related parents within species, when utilized in cross breeding programme, are likely to produce a wide spectrum of variability (Arunachalam, 1981). D^2-statistic developed by Mahalanobis (1936) was used to measure genetic divergence and to classify the genetic stock into distinct groups.

The experimental material comprised of 80 bunch groundnut genotypes. The experimental was laid out in Randomized Block Design with three replications at instructional Farm of College of Agriculture Junagadh Agricultural University, Junagadh under irrigated condition during summer 2006. Each entry was accommodated in a single row of 3.0 m length with a spacing of 30 x 10 cm. The observations were recorded on five randomly selected plants in each entry and replication and their mean values were used for the analysis of genetic divergence using Mahalanobis's D^2-statistics.

The analysis of variance revealed significant differences among the genotypes for all the characters under study thereby indicating the presence of ample variability among the genotypes. On the basis of magnitude of D^2 values all the 80 genotypes of groundnut for 14 characters showed that the generalized distance (D^2) between two populations varied from 8.43 to 26.91, which was an indicator of considerable diversity available in the material evaluated. On the basis of D^2-values, 9 clusters were formed from 80 genotypes (Table 1). The cluster I was the largest, accommodating as many as 19 genotypes followed by cluster II with 17 genotypes from different origins. Cluster III possessed 15 genotypes, while clusters IV and V contained 6 and 8 genotypes, respectively and clusters VI, VII and VIII possessed 4 genotypes each. Cluster IX having 3 genotypes. The clustering pattern of genotypes showed that the genotypes of different origins were clubbed into one cluster whereas, the genotypes belonging to same state or origin were grouped into different clusters indicating that the geographic distribution was not the sole criterion of genetic diversity. Murthy and Arunachalam (1966) also stated that genetic drift and selection in different environments could cause greater diversity than geographic distance. Further, the free exchange of seed materials among the different regions consequently causes characters constellations because of the human interference and material may loose its individuality. The results obtained in the present study are in accordance with the findings of Yadava *et al.* (1991), Golakia and Makne (1992), Katule *et al.* (1992), Reddy and Reddy (1993) and Venkataravana *et al.* (2000) who also reported no parallelism between geographic distribution and genetic diversity. Intra-cluster distance values were lower than the inter- cluster distances. Thus, the genotypes included within a cluster tended to diverse less from each other. Intra-cluster distance (D) ranged from 8.43 to 12.97 for

cluster VI and VIII, respectively (Table 3). The maximum inter-cluster distance (D) was observed between cluster I and VIII (D=26.91) followed by that between cluster IV and VIII (D=25.90), cluster III and VIII (D=25.62) and cluster II and VIII (D=25.25), while the closest proximity was noticed between the cluster II and III (D=11.22). Inter-cluster distance is the main criterion for selection of genotype. In this context, the genotypes from cluster I, II, III and IV could be selected as parents for hybridization with those of cluster VIII. A wide to moderate range of variation for several characters among clusters was noticed (Table 3). However, the differences were more pronounced for number of secondary branches/plant and number of aerial pegs/plant. The present findings are in conformity with those reported earlier in groundnut by Golakia and Makne (1992), Katule *et al.* (1992) and Reddy and Reddy (1993).The clustering pattern could be utilized in selecting the parents and deciding the cross combinations which may generate the highest possible variability for various traits. The genotypes with high values of divergent clusters can be used in hybridization programme for further selection and improvement. In the present study, the cluster VIII differed from other clusters in respect of pod yield/plant, number of secondary branches/plant, number of aerial pegs/plant, number of kernels/pods, 100-kernel weight and harvest index. The cluster I had desirable value for days to 50% flowering and days to maturity. The cluster IV and III had desirable values for shelling percentage and oil content, respectively. The analysis for percent contribution of various characters toward expression of total genetic divergence indicated that number of secondary branches/plant (37.09%) followed by shelling per cent (22.53%) , number of aerial pegs (14.34%), oil content (11.71%) and number of under ground pegs (4.97%) contributed maximum towards divergence. These characters accounted for more than 90% of the total divergence in the material investigated. Therefore, in the present investigation based upon high yielding genotypes and large inter-cluster distances, it is advisable to attempt crossing of the genotypes from cluster I cluster IV cluster III and cluster II with genotypes of cluster VIII. This may lead to broad spectrum of favourable genetic variability for pod yield improvement in groundnut.

Table 1 Grouping of 80 genotypes of bunch groundnut in various clusters on the basis of D^2 statistics

Cluster	Number of Genotypes	Name of the genotypes	Origin
I	19	URR 304	Maharashtra
		ICAS 109	Andhra Pradesh
		JB FDR 29, JB(E) 336, JE 6, JB 459, JB HOC 6, JB 904, GG 2, GG 4, GG 5, GG 6, GG 7, JB 823, JB 605, J 28,	Gujarat
		Jawan	Orissa
		BDH 510	Karnataka
		NCAC 995	U.S.A.
II	17	JB 436, JB 60, JB FDR 59, Girnar 1, JBD 36, FeEsg 10, FeEsg 8	Gujarat
		AK 7171, TG 22, TG 3, AK 408	Maharashtra
		DH 20	Karnataka
		NIAC 1727	U.S.A.
		DSA 201	Argentina
		EC 21139, EC 21051	Cuba
		Kisan	Orissa
III	15	ICGV 87935, ICGV 92127,**ICGV 89359, ICGV 86590, ICGS 10, ICG FDRS 10**	Andhra Pradesh
		EC 100827	Paraguay
		J 54, JB HOC 4, JB 452	Gujarat
		TG 40, TG 50, TAG 24	Maharashtra
		ALR 1	Tamil Nadu
		R 9251	Karnataka
IV	6	GC 400,JB 779,JB 959, JB FDR **55**	Gujarat
		VRI 4	Tamil Nadu
		BH 532	Bihar
V	8	JB 579, JB 696	Gujarat
		AH 7228, AK 159	Maharashtra
		SG 84	Punjab
		ICGS 76, ICGV 86934	Andhra Pradesh
		EC 24405	South Africa
VI	4	AH 8253, AH 6902	Maharashtra
		Gemuma	Sudan
		CSMa 841	Uttar pradesh
VII	4	IJS 71	Andhra pradesh
		NCAC 519	U.S.A.
		HNG 37	Rajasthan
		VG 8934	Tamil Nadu
VIII	4	ICHMG 88409, ICHMG 88398	Andhra Pradesh
		JVB 148, JVB 185	Gujarat
IX	3	M 522, M 335	Punjab
		JVB 151	Gujarat

Table 2 Average inter- and intra-cluster distance ($D=D^2$) values in bunch groundnut

	I	II	III	IV	V	VI	VII	VIII	IX
I	8.84	11.23	11.81	14.26	14.09	13.60	19.04	26.91	21.70
II		8.82	11.22	15.95	12.54	12.38	18.60	25.25	18.21
III			9.83	17.26	12.80	14.17	18.56	25.62	18.70
IV				10.91	14.81	17.36	21.12	25.90	22.94
V					10.12	11.56	14.54	19.23	13.86
VI						8.43	11.72	18.82	14.25
VII							9.55	15.29	13.48
VIII								12.97	15.18
IX									9.93

Table 3 Cluster means for 14 different characters in 80 genotypes of bunch groundnut

Clusters	Pod yield/ plant (g)	Days to 50% flowering	Days to maturity	No. of primary bran./plant	No. of secondary bran./plant	Plant height (cm)	No. of aerial pegs/plant	No. of underground pegs/plant	Biological yield/plant (g)	No. of kernels/ pod	100 kernel weight (g)	Harvest index (%)	Shelling per cent	Oil content (%)
I	13.1	47.8	115.3	4.7	1.2	22.0	4.4	28.2	33.8	2.0	37.3	38.6	71.6	48.4
II	11.6	48.4	116.2	4.7	1.3	17.8	5.5	27.7	28.3	1.9	34.8	40.6	66.0	48.5
III	12.8	48.9	116.5	5.0	1.6	20.7	4.4	30.7	31.9	1.9	40.3	40.3	67.3	51.2
IV	11.1	48.9	116.6	5.0	1.4	21.1	13.6	31.3	32.0	2.0	35.2	35.5	73.6	48.5
V	12.2	49.2	116.5	5.5	3.5	19.5	8.7	33.8	31.9	2.0	37.8	38.4	67.4	49.7
VI	11.6	50.3	117.7	4.6	4.3	22.1	4.3	28.5	31.2	1.8	38.9	38.0	68.2	47.5
VII	11.0	52.5	120.0	5.4	6.7	24.4	4.0	25.3	34.2	1.9	35.3	32.9	70.0	49.4
VIII	14.1	49.4	118.1	5.2	9.2	21.8	10.5	30.1	33.4	2.1	43.1	41.8	66.9	49.8
IX	10.3	50.1	117.6	5.3	6.2	15.1	6.9	34.3	32.4	2.0	35.5	33.6	62.6	50.4
Mean	12.2	48.9	116.5	4.9	2.6	20.4	6.1	29.6	31.8	2.0	37.4	38.7	68.5	49.2
SEm ±	1.1	1.1	1.2	0.4	0.5	2.4	1.1	3.3	2.2	0.1	3.1	2.4	1.5	0.6
C.V.%	15.8	4.0	1.7	13.8	31.3	20.4	31.1	19.3	11.8	8.8	14.2	10.8	3.7	2.1
Percentage contribution of characters towards total divergence														
No. of times appearing first	22	0	14	23	1172	109	453	157	22	74	32	0	712	370
Per cent contribution	0.7	0.0	0.4	0.7	37.1	3.5	14.3	5.0	0.7	2.3	1.0	0.0	22.5	11.7

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Short communication

Phenotypic evaluation of RILs for rust and late leaf spot and their association on productivity traits in groundnut, *Arachis hypogaea* L.

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Abstract

The mapping population used in the present study was showing better genetic variability and consistent positive association between the stages and seasons for both the diseases i.e., rust and leaf spot indicating the usefulness of population for mapping and tagging for these two diseases using appropriate molecular markers. The association pattern for productivity with rust indicates the importance of resistance for improved productivity in groundnut. However, the association was not clearly observed with late leaf spot revealing the need to screen in multiple seasons.

Keywords: Groundnut, rust, late leaf spot

Groundnut (*Arachis hypogaea* L.) is damaged by late leaf spot and rust diseases (Kokalis-Burette *et al.*, 1997). Moderate level of resistance is available in the cultivated groundnut gene pool for late leaf spot and several wild *Arachis* species also possess very high levels of rust resistance.

There has been limited success in transferring resistance from wild *Arachis* to cultivated groundnut, mainly because of inter-specific compatibility barriers, resistance being linked with many undesirable pod/seed characteristics and longer periods required for developing stable tetraploid interspecific derivatives. However, an inter-specific derivative GPBD 4 released at U.A.S. Dharwad combined early maturity, high yield potential and high shelling outturn with minimum yield reduction due to high level of resistance to rust and late leaf spot with higher pod growth rate, partitioning coefficient and harvest index (Gowda *et al.*, 2001). The present study has aimed at evaluating the mapping population for the genetic variability components including heritability and correlation among these two diseases and the correlation of them with important productivity traits.

A mapping population consisting of 146 recombinant inbred lines obtained (F_9:F_{10}) by crossing TG 26 x GPBD 4 was used for the study. TG 26 is an early maturing, semi dwarf, erect variety with high pod growth rate, high harvest index, greater partitioning efficiency, tolerance to bud necrosis and rust with high linoleic acid content but susceptible to LLS (Kale *et al.*, 1997; Badigannavar *et al.*, 2002). GPBD 4 developed at University of Agricultural Sciences, Dharwad is a second cycle product of interspecific hybridization with desirable combination of early maturity, high yield, high pod growth rate, desirable pod and kernel features, high oil and protein content, better oleic/linoleic (O/L) ratio, resistant to late leaf spot and rust (Gowda *et al.*, 2002). Phenotyping for both the diseases was carried out according to modified 9 point scale Disease scoring on rust and LLS was recorded in Rainy 2005 and Rainy 2007 at 70 days (stage I) and 90 days (stage II). The productivity traits were evaluated during rainy 2007 for each RIL in two replications.

Phenotypic data obtained for both the diseases were subjected for pooled analysis of variance (ANOVA), mean and range and genetic variability components were estimated for individual season as well as pooled across the seasons. Correlation between the seasons, within the season between the stages and between both the diseases was done and the mean replicated data obtained for six productivity traits during rainy 2007 was used for correlation analysis with both rust and LLS during the same seasons. All the statistical parameters were estimated using SPAR software.

Mapping population exhibited significant variation for rust and LLS. Significant seasonal and genotype x season interaction indicated the need for screening in multiple environments (Table 1). Khedikar (2008) also found significant G x E interaction for these two diseases in a mapping population of 268 RILs obtained from the cross TAG 24 x GPBD 4.

The components of variation *viz.*, PCV and GCV revealed substantial variation for both the diseases (Table 2). Further, moderate to high heritability and GAM indicated highly heritable nature of the variation. The estimates of components of variation were very low in one of the seasons (Rainy, 2007) for LLS which could be due to predominance of rust in that season. Usually both LLS and rust occur together but the incidence and severity vary between localities and seasons (Subramanyam *et al.*, 1984) and relative occurrence of these two diseases can

influence precision and assessment of diseases in the genotypes. When compared across stages, the components were low at later stage especially for LLS indicating suitability of first stage for better discrimination. The reduction in different components of variability under pooled analysis was more for LLS as compared to rust indicating preponderance of G x E interaction.

The disease scores between the stages in a season and between seasons at a particular stage were highly correlated revealing the consistency of disease reaction in the individual genotypes for both the diseases in spite of significant G x E interaction. In contrast, correlation between rust and LLS was negative indicating differential prevalence of resistance in the RILs for the two diseases (Table 3).

Most of the productivity traits exhibited negative correlations with rust disease indicating favorable influence of rust resistance on productivity (Table 4). In contrast, there was a lack of association for many of the productivity traits with late leaf spot. LLS at stage II had a negative correlation with 100-seed weight indicating its favorable association with resistance. At Stage I, positive correlation was evident with number of pods/plant and pod yield/plant revealing the association of higher productivity with susceptibility.

Table 1 Pooled ANOVA for rust and late leaf spot traits in TG 26 x GPBD 4 mapping population

Traits/Source of variation	Mean sum of squares							
	Season	*Replication*	*S x R*	*Genotypes*	*S X G*	*Error*	*CV*	*Sed*
Diseases								
Df	1	1	1	145	145	290		
Rust								
Stage I	51.48**	0.43	1.157	1.42**	0.58**	0.32	17.24	0.39
Stage II	33.08**	2.09	0.29	3.43**	1.60**	0.47	15.98	0.48
Late leaf spot								
Stage I	263.12**	30.75	75.51	4.44**	2.42**	1.11	21.33	0.74
Stage II	234.40**	15.78	0.36	2.11**	1.27**	0.73	12.58	0.60

Table 2 Mean, range and genetic variability components for rust and late leaf spot in TG 26 x GPBD 4 mapping population

Traits	*Parents*		RILs					
	TG 26	GPBD 4	Mean	Range	PCV	GCV	h^2	GAM
			Rainy 2005					
Rust (Stage I)	3.0	2.0	2.9	2.0-5.0	31.4	23.6	56.6	36.6
Rust (Stage II)	5.0	3.0	4.0	2.0-8.0	37.5	31.7	71.7	55.2
LLS (Stage I)	7.0	2.0	5.6	2.5-7.0	26.4	23.2	77.2	42.2
LLS (Stage II)	8.0	3.0	6.1	3.0-8.0	19.4	14.2	52.9	21.2
			Rainy 2007					
Rust (Stage I)	5.0	2.0	4.8	2.0-8.0	41.8	38.2	83.7	7.1
Rust (Stage II)	7.5	3.0	6.4	3.0-9.0	33.2	28.9	75.7	51.9
LLS (Stage I)	4.0	2.5	4.2	2.0-9.0	35.7	18.3	26.2	19.1
LLS (Stage II)	7.5	4.0	7.4	5.0-9.0	13.2	5.8	19.5	5.3
Plant height (cm)	15.9	29.4	23.0	8.0-33.3	21.9	16.0	53.3	1.0
Number of branches	4.7	4.5	6.0	3.0-13.5	22.5	0.5	0.1	0.0
Number of pods/plant	13.0	16.6	16.7	5.5-45.5	34.8	12.8	13.6	0.6
Pod yield/plant (g)	7.0	10.2	12.9	2.7-37.2	37.5	17.8	22.6	1.3
Shelling %	68.7	75.9	76.6	61.7-87.5	5.2	1.9	13.9	0.0
100-seed weight (g)	32.6	50.7	34.2	17.3-58.7	21.6	14.7	46.4	20.6
			Across seasons					
Rust (Stage I)	4.0	2.1	3.7	2.1-5.1	28.7	22.7	62.5	37.0
Rust (Stage II)	5.0	2.7	4.9	2.7-6.6	27.9	22.1	62.7	36.1
Rust (Stage III)	6.4	3.0	5.6	3.0-7.5	26.4	18.7	50.1	27.2
LLS (Stage I)	5.5	2.2	4.9	2.7-7.0	25.7	14.3	31.2	16.4
LLS (Stage II)	7.7	3.5	6.7	5.5-8.0	14.2	6.6	22.0	6.4

Table 3 Correlation between rust and late leaf spot in various seasons

Traits	Rust Stage I	Rust Stage II	Late Leaf spot Stage I	Late Leaf Spot Stage II
Rust Stage I				
Rainy 2005	1.000	0.905**	-0.505**	-0.430**
Rainy 2007	1.000	0.943**	-0.273**	0.105*
Rust Stage II				
Rainy 2005		1.000	-0.591**	-0.526**
Rainy 2007		1.000	-0.301**	0.034
Late Leaf spot Stage I				
Rainy 2005			1.000	0.858**
Rainy 2007			1.000	0.441**
Late Leaf spot Stage II				
Rainy 2005				1.000
Rainy 2007				1.000

Table 4 Correlation for diseases (rust and LLS) with productivity traits in TG 26 x GPBD 4 mapping population

Traits	*LLS Stage I*	*LLS Stage II*	*Rust Stage I*	*Rust Stage II*	*Rust Stage III*	*Rust (I) Stage I*	*Rust (I) Stage II*
Plant height	0.208*	-0.161	0.124	0.042	-0.034	0.004	-0.028
No. of Branches	-0.006	-0.007	-0.001	0.019	0.006	0.021	-0.002
Number of pods/plant	0.211*	0.011	-0.238**	-0.264**	-0.298**	-0.297**	-0.322**
Pod yield/plant	0.242**	0.012	-0.314**	-0.318**	-0.344**	-0.386**	-0.402**
shelling %	-0.020	-0.064	-0.314**	-0.236*	-0.265**	-0.250**	-0.179*
100-seed weight	0.145*	-0.152*	-0.288**	-0.301**	-0.296**	-0.310**	-0.303**

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Short communication

Heterosis and genetic architecture for quality traits in sesame, *Sesamum indicum* L.

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Abstract

The studies on heterosis and genetic architecture for quality traits in sesame, *Sesamum indicum* L. indicated that non-additive gene action was predominantly responsible for inheritance of quality traits, heterosis breeding could be the best breeding method for improvement.

Keywords: *Sesamum indicum*, genetic architecture

Sesame (*Sesamum indicum* L.), is a very ancient oilseed crop, generally known as til, tal and gingelly. India is the largest producer and exporter of sesame in the world. The genetic make up of genotypes for inherited traits can be well understood by the study of genetic parameters. The combining ability analysis has been utilized to know the nature and extent of gene action controlling the inheritance of yield and quality traits for getting better recombinants. The present investigation was carried out to evaluate genotypes of sesame for their heterosis and combining ability.

A half diallel set was made using 10 sesame genotypes during *kharif* 2004.The 10 parents and their 45 F_1s were evaluated in a Randomized Block Design with three replications under four environments created by four different dates of sowing during *kharif* 2005. The field experiment was conducted at the main castor and mustard research station, S.D. Agricultural University, Sardarkrushinagar with 45 x 15 cm spacing. The observations were recorded on five randomly selected plants of each genotype in each replication and each environment. The data were analyzed for heterosis according to Fonseca and Petterson (1968) and combining ability for single environment using Griffing (1956), Model 1 and Method II.

The analysis of variance for combining ability over environments was carried out and the mean squares are presented in Table 1. The results revealed that mean squares due to GCA and SCA were highly significant for all the traits. The ratio of $\delta^2 gca/\delta^2 sca$ was less than unity suggesting the major role of non-additive gene action for the inheritance of all the characters except for protein content. For protein content variance ratio of $\delta^2 gca/\delta^2 sca$ was greater than unity indicating the importance of additive type of gene action.

The parents, C 1013, AT 123 and GT 2 were found to be good general combiners for seed yield (Table 2). Among these, C 1013 was also found to be best combiner for oil content and protein content. It was further noted that involvement of these parents in hybridization has resulted into hybrids expressing useful heterosis for various traits. The parent C 1013, Mrug 1 and Tapi were good combiners for oil content, whereas, parent Tapi, C 1013 and PT 64 were good combiners for protein content. Parent C 1013 should be utilized in breeding programme for improvement of seed yield and quality traits. Similar finding was also noted by Karuppaiyan and Sundaresan (2002), Krishnaiah *et al.* (2003) and Prajapati *et al.* (2006).

The estimates of *sca* effects pooled over environments revealed that GT 2 x GT 10, Mrug 1 x PT 64 and C 1013 x ABT 23 were found to be best specific combiners for seed yield, which also showed significant desirable *sca* effects for quality characters. The crosses, Mrug 1 x PT 64, Mrug 1 x ABT 26 and GT 2 x ABT 23 for oil content and C 1013 x GT 10, GT 10 x Tapi and Tapi x AT 123 for protein content were found to be best specific combiners.

A comparative study of hybrids on the basis of per se performance and sca effects revealed that the most of the crosses, which produced maximum yield, had at least one parent as good combiner for seed yield. This suggested that the parent with higher *gca* effects are desirable for a hybrid having *sca* effects for realization of the maximum heterosis. A perusal of the data given in Table 2 also revealed that, the cross having higher desirable estimates of *sca* which resulted from good x good, good x average and also good x poor general combiners. This supports the importance of both additive and non-additive genetic variance in quality traits.

The hybrid, ABT 23 x ABT 26 expressing the highest heterobeltiosis for seed yield/plant followed by Mrug 1x PT 64 also manifested high heterobeltiosis for oil content on pooled basis (Table 2).

An over view of the results suggested that since non-additive gene action was predominantly responsible

for the inheritance of all the traits, heterosis breeding could be the best breeding method for improvement. Since both additive and non-additive genetic variances are important, to take advantage of both types of gene action, reciprocal recurrent selection (Dixit, 1976) or biparental mating (Krishnadoss *et al.* 1987) followed by modified recurrent selection may be resorted for the improvement of yield and yield related traits for the development of high yielding stable genotypes of sesame.

Table 1 Pooled analysis of variance of combining ability for different quality characters in sesame

Source of variation	d. f.	Seed yield/plant	1000–seed weight	Oil content	Protein content
gca	9	10.31**	0.74**	59.09**	72.31**
sca	45	3.39**	0.12**	33.06**	0.86**
Error	432	0.49	0.01	0.37	0.06
$\delta^2 gca$	-	0.21	0.02	1.22	1.51
$\delta^2 sca$	-	0.73	0.03	8.17	0.20
$\delta^2 gca/\delta^2 sca$	-	0.28	0.58	0.15	7.49

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

Table 2 Three best performing parents, best general combiners and best performing hybrids along with their *sca* effects and best specific cross combinations and best heterotic combinations in desired direction for various characters in sesame

Character	Best performing parents	Best general combiners	Best performing hybrids	Status of parents	*sca* effects	Best cross combination	Best heterotic combination over	
							MP	BP
Seed yield/ plant	GT 2 AT 123 C 1013	C 1013 AT 123 GT 2	GT 2 x GT 10 C 1013 x ABT 23 ABT 26 x AT 123	G x A G x P A x G	2.71** 1.49** 1.40**	GT 2 x GT 10 Mrug 1 x PT 64 C 1013 x ABT-23	Mrug 1 x PT 64 C 1013 x ABT 23 GT 2 x GT 10	ABT 23 x ABT 26 Mrug 1 x PT 64 C 1013 x ABT 23 GT 2 x GT 10
1000-seed weight	Mrug 1 PT 64 Tapi	Mrug 1 Tapi GT 1	GT 1 x Tapi Mrug 1 x ABT 23 Mrug 1 x Tapi	G x G G x A G x G	0.30** 0.32** 0.04	Mrug 1 x ABT 23 GT 1 x Tapi GT 1 x ABT 123	GT 1 x ABT 23 Mrug 1 x ABT 23 GT 1 x Tapi	GT 1 x Tapi GT 10 x ABT 23 GT 1 x ABT 23
Oil content	GT 10 C 1013 GT 1	C 1013 Mrug 1 Tapi	Mrug 1 x PT 64 Mrug 1 x AB 26 C 1013 x Mrug 1	G x P G x P G x G	5.98** 5.37** 1.82**	Mrug 1 x PT 64 Mrug 1 x AB 26 GT 2 x ABT 23	Mrug 1 x ABT 26 Mrug 1 x PT 64 C 1013 x ABT 26	Mrug 1 x PT 64 Mrug 1 x ABT 26 GT 2 x AT 123
Protein content	Tapi C 1013 PT 64	Tapi C 1013 PT 64	C 1013 x Tapi PT 64 x Tapi C 1013 x PT 64	G x G G x G G x G	0.03 0.20 0.29**	C 1013 x GT 10 GT 10 x Tapi Tapi x AT 123	Mrug 1 x PT 64 Mrug 1 x Tapi C 1013 x GT 10	Mrug 1 x GT 10 C 1013 x PT 64 C 1013 x Tapi

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

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Short communication

Evaluation of progenies selected from random mated population of safflower, *Carthamus tinctorius* L. using GMS lines

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Abstract

Safflower (*Carthamus tinctorius* L.) is one of the most important *rabi* oilseed crop belonging to family Asteraceae. Low seed yield and low market prices, due to low oil content coupled with long duration and susceptibility to biotic and abiotic stresses, restricted the spread of safflower crop beyond traditional safflower growing area of the region. So, this crop needs further improvement genetically with agronomic intervention. Recurrent selection is efficient method of population improvement which increases the frequency of desirable genes, maintain high genetic variability and breaks undesirable linkages. Genetic male sterility system available in safflower may help in this direction.

Keywords: Safflower, genetic male sterile

The material of the present study derived from the GMS based hybrids made earlier. During *rabi* 2002-03, 72 hybrids were made using nine GMS lines and eight pollen parents. These hybrids were evaluated during 2003-04 and superior 54 hybrids were selected to constitute base population-I. Equal amount of seeds of 54 hybrids (F_1's seeds) were composited and sown during *rabi* 2004-05 for recombination in open pollinated condition in isolation and in this F_2 bulk 256 male sterile plants were tagged at the time of flowering and harvested individually. Out of these 196 plants having sufficient seeds were selected for evaluation and sown during *rabi* 2005-06 along with two checks *viz.*, AKS 207 and Bhima keeping remnant seeds to constitute next recombination cycle. Material was sown in two replications in modified Randomized Block Design. Each replication consisted of ten blocks and each block consisted of 20 progenies along with two checks. The observations were recorded on ten characters (Table 2). The data were statistically analysed to estimate mean, genotypic and phenotypic variances, genotypic and phenotypic coefficient of variation (Burton, 1951), heritability (broad sense) as per Johnson *et al.* (1955) and genetic advance (Lush, 1949). As well as the simple genotypic, phenotypic correlation coefficient were worked out from the respective variances and covariances as per Hayes *et al.* (1955). Mean performance (Table 1) indicated that maximum range was existing in plant height followed by number seeds per capitulum, seed yield/plant and number of capitula/plant, primary branches/plant, oil content and 100 seed weight. Similar trend was reported by Eckebil *et al.* (1977) and Flores *et al.* (1986).

PCV was greater than GCV for all the characters indicating apparent variation was due to both environment and genotype (Table 2). Estimates of GCV and PCV were low for days to maturity and 30.33 and seed yield/plant. Number of branches, number of seeds/capitulum and number capitula/plant exhibited high GCV and PCV indicate large amount of variation and less amenability to environmental fluctuations. Similar results were recorded by Senapati *et al.* (1999) and Sarang *et al.* (2004). Low GCV and PCV for days for maturity and 50% flowering are in conformity with the finding of Nair *et al.* (2006). Heritability (broad sense) was low 64.31% for oil content and it was high 84.97% for seed yield/plant. Characters exhibited high heritability indicated greater scope for selection for improvement of yield and field component. High heritability are in conformity with the findings of Senapati *et al.* (1999) and Goyal (2006).

Expected genetic advance as mean of population at 5, 10 and 20% selection intensity was high for seed yield/plant. EGA over check varieties, i.e., AKS 207 and Bhima at 5, 10 and 20% selection intensity was high for seed yield/plant over AKS 207 and Bhima, respectively. High heritability along with high expected genetic advance indicated the presence of additive gene action.

Higher genotypic correlations than the phenotypic one indicated inherent relationship between the characters. Table 4 revealed that seed yield/plant had positive and significant association with number of primary branches/plant and number of capitula/plant at both genotypic and phenotypic levels. Similar findings was also recorded by Jawanjal *et al.* (2006). Seed yield/plant had significant positive correlation with number of seeds/capitulum at genotypic level. Diwakar *et al.* (2006) observed same results. Seed yield/plant had positive significant association at genotypic and phenotypic level with oil content which is in conformity with the findings of

Esendal and Tosun (1972) and Tuncturk and Ciftci (2004). In general seed yield in negatively correlated with oil content as per Ghongade *et al.* (1993). He also suggested that it is possible to break such undesirable relations by random mating among segregants followed by selection. Seed yield/plant had significant and negative correlation with days to 50% flowering at genotypic and phenotypic levels. These findings are also consonance with the findings of Diwakar *et al.* (2006). The present investigation clearly showed that the traits, *viz.*, number of primary branches/plant, number of capitula/plant and number of seed/capitulum had strong association with seed yield/plant. This indicated that direct selection for these traits will definitely enhance the seed yield in safflower.

Table 1 Mean performance progenies

Statistic	Days to first flowering	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/ plant	No. of capitula/ plant	No. of seeds/ capitulum	100 seed wt. (g)	Oil content (%)	Seed yield/plant (g)
Minimum (Progeny No.)	74 (PI-140)	82 (PI-82)	139 (PI-73)	75.2 (PI-18)	3.8 (PI-188)	6.4 (PI-188)	10.4 (PI-83)	4.66 (PI-95)	27.02 (PI-63)	8.73 (PI-83)
Maximum (Progeny No.)	103 (PI-194)	110 (PI-196)	160 (PI-196)	125.2 (PI-195)	17.4 (PI-193)	42.4 (PI-46)	58.0 (PI-178)	7.27 (PI-187)	33.48 (PI-152)	55.53 (PI-167)
Range	29	28	21	50.0	13.6	36.0	47.6	2.61	6.46	46.80
Mean (progenies)*	85.82	91.10	145.80	95.87	9.89	25.08	27.50	5.91	29.37	29.15
Checks										
AKS-2072	79.5	85.75	142.15	91.09	10.12	26.76	27.3	5.68	30.39	36.76
Bhima**	86.35	92.05	145.65	93.37	10.13	26.34	27.4	5.62	31.26	37.48

* Mean of 196 progenies; ** Mean of check varieties

Table 2 Parameters of genetic variability for different characters

Character	Range	Mean	Genotypic variance	Phenotypic variance	GCV (%)	PCV (%)	Heritability % in (Broad sense)	GA (%)	EGA as (%) over mean of population (at 5%)
Days to first flowering	74-103	85.56	13.53	18.12	4.29	4.97	74.68	6.54	7.65
Days to 50% flowering	82-110	90.90	10.24	12.32	3.52	3.86	83.18	6.81	6.81
Days to maturity	139-160	145.62	8.09	10.10	1.95	2.18	80.07	5.24	3.61
Plant height (cm)	75.2-125.2	95.53	33.59	41.43	6.06	6.73	81.05	10.74	11.23
No. of branches/plant	3.8 - 17.4	9.91	5.50	7.24	23.66	27.15	75.89	4.20	42.46
No. of capitula/plant	6.4 - 42.4	25.21	29.81	40.38	21.65	25.19	73.82	9.66	38.32
No. of seeds/capitulum	10.4 - 58	27.51	39.92	52.80	22.96	26.40	75.60	11.31	41.10
100 seed weight (g)	4.66 - 7.27	5.89	0.223	0.285	8.01	9.06	78.23	0.86	14.61
Oil content (%)	27.02-33.48	29.51	1.26	1.96	3.81	4.75	64.31	1.85	6.30
Seed yield/plant (g)	8.73 - 55.53	29.89	82.27	96.82	30.33	32.91	84.97	17.22	57.61

GCV = Genotypic coefficient of variation; PCV = Phenotypic coefficient of variation

Table 3 Estimates of expected genetic advance over mean of population and over checks AKS-207 and Bhima

Unit of evaluation and selection	Cycle	Selection intensity#	Days to first flowering	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No .of capitula/plant	No. of seeds/ capitulum	100 seed wt. (g)	Oil content	Seed yield/ plant (g)
					Expected genetic advance as per cent over mean of population							
Progeny	1	5	7.65	6.61	3.61	11.23	42.46	38.32	41.1	14.61	6.30	57.61
		10	6.53	5.65	3.08	9.59	36.27	32.74	35.1	12.48	5.38	49.22
		20	5.20	4.49	2.45	7.63	28.85	26.04	28	9.93	4.28	39.15
					Expected genetic advance as per cent over AKS-207							
Progeny	1	5	8.23	7.01	3.69	11.78	41.59	36.11	41.48	15.13	6.12	46.85
		10	7.03	5.99	3.16	10.06	35.53	30.85	35.44	12.93	5.23	40.02
		20	5.59	4.76	2.51	8.00	28.26	24.54	28.19	10.28	4.16	31.84
					Expected genetic advance as per cent over Bhima							
Progeny	1	5	7.58	6.53	3.61	11.49	41.55	36.69	41.35	15.31	5.95	45.95
		10	6.47	5.58	3.08	9.82	35.50	31.35	35.32	13.08	5.08	39.26
		20	5.15	4.44	2.45	7.81	28.24	24.93	28.10	10.40	4.04	31.22

#=Response to selection of top 5% (K=2.06), 10% (K=1.76) and 20% (K=1.40) of large number of progenies, where 'K' is the standardized selection differential

Table 4 Genotypic and phenotypic correlation coefficient among different characters in safflower

Character		Days to first flowering	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of capitula /plant	No. of seeds/ capitulum	100 seed wt. (g)	Oil content	Seed yield/ plant (g)
Days to first flowering	G	1.00	0.918**	0.655**	0.636**	-0.342**	-0.292**	0.190**	0.004	-0.044	-0.247**
	P	1.00	0.797**	0.514**	0.480**	-0.230**	-0.175*	0.136	-0.013	-0.030	-0.190**
Days to 50% flowering	G		1.00	0.762**	0.631**	-0.279**	-0.198**	0.136	-0.019	0.013	-0.198**
	P		1.00	0.650**	0.511**	-0.222**	-0.143*	0.107	-0.032	0.032	-0.166*
Days to maturity	G			1.00	0.451**	-0.159*	-0.107	0.150*	-0.074	0.092	-0.158*
	P			1.00	0.344**	-0.104	-0.091	0.109	-0.049	0.060	-0.132
Plant height (cm)	G				1.00	-0.244**	-0.140*	0.060	0.075	-0.131	-0.099
	P				1.00	-0.193**	-0.100	0.078	0.076	-0.066	-0.105
No. of primary branches/ plant	G					1.00	0.708**	-0.425**	-0.036	0.110	0.245**
	P					1.00	0.612**	-0.309**	-0.045	0.057	0.205**
No. of capitula/ plant	G						1.00	-0.431**	-0.043	0.105	0.503**
	P						1.00	-0.324**	-0.042	0.091	0.418**
No. of seeds/ capitulum	G							1.00	-0.102	0.143*	0.150*
	P							1.00	-0.063	0.134	0.126
100 seed wt. (g)	G								1.00	-0.325**	-0.186**
	P								1.00	-0.224**	-0.149*
Oil content (%)	G									1.00	0.516**
	P									1.00	0.373**

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

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Short communication

Genetic divergence in linseed, *Linum usitatissimum* L. under salt stress condition

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Abstract

Genetic divergence under salt stress conditions for nine yield contributing characters were studied in linseed using 105 diverse genotypes including five checks. The analysis of variance revealed highly significant differences of means for all the characters. The 105 genotypes were grouped into twelve clusters where, cluster X was the largest containing 24 genotypes followed by cluster IV with 12 genotypes whereas, cluster I contained only 3 genotypes. The inter-cluster distance was the maximum between cluster I and VI based on inter-cluster distance and per se performance of genotypes, the entries, *viz.*, A-18-1-2, A-6-1-5, 5/37-2/1-61/1, 5/47, 9x12, 477-3/2, A-62 and A-44 can be intercrossed to obtain high heterotic response and also to recover desirable transgressive segregants. Seed yield/plant contributed maximum divergence (80.7%) followed by number of capsules/plant (8.2%) and days to flowering (6.6%).

Keywords: Linseed, D^2 statistic, genetic divergence

Linseed (*Linum usitatissimum* L.) is one of the important oilseed crops of India. The crop is grown under diverse agro-production situations, across the climatic and geographic boundaries, which necessitated the development of more productive varieties of diverse origin. Crosses between divergent parents usually produce greater heterosis than those between closely related ones (Moll and Stuber, 1971). Genetic divergence studies are the vital tools for the evaluation of germplasm lines and selection of parents for the breeding programme. So, the present study was undertaken to measure genetic diversity among the germplasm lines.

The material for the present study consisted of 100 linseed germplasm accessions from GMU-01 to GMU-100 along with five checks i.e., Gaurav, Neelum, Kiran, T-397 and Padmini. The experiment was conducted at Crop Research Farm, Nawabganj of the university during *rabi* 2002 under salt sick soil (pH 8.9). Each accession was sown in single row of 3m length with a spacing of 40cm. between row and 4-5 cm between plants. The experiment was laid out in Randomized Complete Block Design in three replications. In each accession, five plants were randomly selected for collection of data on yield and its component traits. The data was analysed as per Mahalanobis D^2 statistics (Mahalanobis, 1936) and Toucher's method as described by Rao (1952) for determining group. Average intra and inter cluster distances were estimated as per the procedure outlined by Singh and Choudhary (1977).

The analysis of variance revealed significant differences among the genotypes for all the traits under study except number of seeds per capsule. Based on D^2 statistics and Toucher's method 105 accessions (100 germplasm + 5 checks) were grouped into 12 clusters (Table 1). Cluster X had the maximum number with 24 genotypes followed by cluster IV with 12 genotypes, cluster III with 10 genotypes, cluster VII, VIII and XI with 9 genotypes, cluster VI and XII with 8 genotypes, clusters IX, II and I with 5, 4 and 3 genotypes, respectively. The genotypes from one source of origin clustered with the genotypes of other source of origin. This indicated that there was no parallelism between geographical distribution and genetic diversity. Three checks (Kiran, T-397 and Padmini) were included in cluster X and one each check i.e., Neelum and Gaurav were grouped into clusters XI and XII, respectively indicating their distinctness or similarity from the germplasm accessions with respect to traits considered. Similar findings were also reported by Chawla and Singh (1984) and Mahto *et al.* (1995) in linseed.

The clusters VI (A-18-1-2, A-6-1-5, 5/37-2/1-61/1, 5/47, 9 x12, 477-3/2, A-62 and A-44) recorded the highest test weight (8.48 g) and technical plant height (35.9 cm). The cluster XII recorded the highest number of capsules/plant (150.4), plant height (75.1 cm) and days to maturity (144.4 days). Seed yield/plant contributes more than 80% followed by number of capsules/plant (8.24%) and days to flowering (6.6%) contributes maximum role for the divergence.

Average intra and inter cluster D^2 values among 105 genotypes (Table 2) revealed that cluster I, X, IV, XI and XII have the minimum intra cluster values *viz.*, 1.32, 2.28, 2.31, 2.92 and 3.00, respectively indicating that genotypes within this cluster were similar. While, cluster V showed

the maximum intra cluster D^2 value (5.24) followed by cluster VI (4.93) and cluster III (4.41) revealing, thereby, the existence of diverse genotypes that fell in these clusters. The inter cluster D^2 values ranged from 3.17 to 43.56. Minimum inter cluster D^2 values were observed between cluster IV and X (3.17) indicating the close relationship among the genotypes included in these clusters. Maximum inter cluster value was observed between II and XII (43.56) followed by cluster II and XI (35.40) and cluster I and XII (33.76) which indicates that genotypes included in these clusters are genetically diverse and may give rise to high heterotic response in early generation and transgressive segregantes in advance generations, if utilized repeatedly in the crossing programme, which in tern may release hidden variability by breaking tight linkages, if any, as reported by Thoday (1960).

Table 1 Grouping of 100 germplasm + checks of linseed in 12 clusters

Cluster	Genotypes	No. of Genotypes
I	1795, 421 × RR-9, 491	03
II	1636, 1541, 1206, 1045	04
III	191×RR-9A, 191×RR-9/2, 302-63-32, 164/1, 121×RR-9-1, 169R-53-2, 149T-126-1, 1C-68-2676, 63/4-34, 39-1	10
IV	A-19-6, A-15-1-2, A-12-1-2, 59/25, 56120, 5629, 5620A, 19×11, A-63, A-51, A-39, A-47	12
V	A-3-1, A-2-1, 1/76, 3/1	04
VI	A-18-1-2, A-6-1-5, 5/37-2/1-61/1, 5/47, 9×12, 477-3/2, A-62, A-44	08
VII	A-4-2-1, 191×RR-9/1, 333-6, A/17/1, 104NP(RR)-573, A-61, A-59, 73×RR-9, 19-1-62	09
VIII	5610, 40617/1, 4602, 1937, 448-5, 476 ENG, 473, 474-3/2, 1491	09
IX	A-10-2-2, 11414, 191-RR-9, 18-RR-9, 18-B-1	05
X	A-6, A-4-3-2, A-3, A-1-3, 5630, 5613, 162-OR-3-1, 107-DOOMA, LC-2045, 1-60, A-58-**A-56, A-52, A-24-1-2,** A-4-2-1, A-40, A-42, A-43, 11×14, EC 97256, LCK-887, Kiran, T-397, Padmini	24
XI	A-4-3-1-13, 5/47-2/1-10/10, A-23-1-1, 9×14, 9×17, 11×12, 11×17, 12×15, Neelum	09
XII	388, A-49, 9×JBP-1986, Jabalpur12 -1986, 11×13, 23/3, 16×RR-9, Gaurav	08
	Total	105

Table 2 Intra and inter cluster (D and D^2) values among 12 clusters in linseed under salt affected soil

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	1.15											
	(1.322)											
II	3.32	1.83										
	(11.022)	(3.348)										
III	4.03	5.21	2.10									
	(16.240)	(27.147)	(4.410)									
IV	4.07	4.83	2.36	1.52								
	(16.564)	(23.328)	(5.569)	(2.310)								
V	3.60	4.25	3.57	3.53	2.29							
	(12.960)	(18.062)	(12.744)	(12.460)	(5.244)							
VI	4.93	5.55	3.41	2.96	3.00	2.22						
	(24.304)	(30.802)	(11.628)	(8.761)	(9.00)	(4.928)						
VII	3.90	4.95	2.61	2.56	3.15	9.92	1.83					
	(15.210)	(24.502)	(6.812)	(6.553)	(9.922)	(8.526)	(3.348)					
VIII	3.09	4.13	4.23	3.23	4.26	3.71	3.47	1.89				
	(9.548)	(17.056)	(17.892)	(10.432)	(18.147)	(13.764)	(12.040)	(3.572)				
IX	3.57	5.13	4.08	4.06	3.66	4.49	3.08	4.32	1.58			
	(12.744)	(26.316)	(16.646)	(16.483)	(13.395)	(20.160)	(9.486)	(18.662)	(3.422)			
X	4.31	5.50	3.31	1.78	3.91	3.11	2.33	2.83	3.70	1.51		
	(18.576)	(3.250)	(10.956)	(3.168)	(15.288)	(9.672)	(5.428)	(8.179)	(13.690)	(2.280)		
XI	5.23	5.95	3.47	3.35	4.21	3.31	2.16	4.13	3.96	2.80	1.71	
	(27.352)	(35.402)	(12.040)	(11.222)	(17.724)	(10.956)	(4.665)	(17.056)	(15.681)	(7.840)	(2.924)	
XII	5.81	6.60	5.06	4.15	5.11	4.65	3.65	4.30	4.92	2.79	2.75	1.72
	(33.756)	(43.560)	(25.603)	(17.222)	(26.112)	(21.622)	(12.673)	(18.490)	(24.206)	(7.784)	(7.562)	(2.958)

Figures in parentheses denote D values

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Short communication

Genetic diversity and variability in sesame, *Sesamum indicum* L.

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Abstract

Genetic divergence was studied by growing 82 genotypes of sesame, Sesamum indicum L. at Agricultural Research Station, Mandor, Jodhpur. The mean sum of squares were significant for all the characters studied except oil content, indicating the presence of variability. Characters like seed yield, primary branches/ plant, capsules/ plant and plant height to first capsule exhibited heritability coupled with high genetic advance revealing that these characters were controlled by additive gene action. The hierarchical cluster analysis indicated the presence of considerable genetic divergence among the genotypes. The genotypes were grouped into eight clusters using Ward's minimum variance method. The inter-cluster Euclidean2 distance was maximum between cluster V and VIII followed by cluster V and VII and cluster II and V which indicated that the genotypes included in these clusters will give high heterotic response and thus better segregants. The maximum cluster means were revealed by cluster V for seed yield, plant height and number of capsules/ plant, cluster II for number of primary branches/plant and cluster III for test weight, while cluster VIII showed minimum cluster means for plant height to first capsule, days to 50% flowering and maturity. Among the eight characters studied seed yield contributed the most (38.9%) towards the divergence of genotypes.

Keywords: Sesame, Euclidean^2 distance analysis, genetic divergence, genetic variability

Bold and shining white seeded sesame also referred as confectionary sesame gaining much more importance in recent years in view of its export potential. Genetic variability and divergence are of great interest to the plant breeders as these play a vital role in framing a successful breeding programme. The objective of the research was to assess quantum of variability, heritability, genetic advance and genetic diversity in available breeding lines so that breeding efforts can be initiated to evolve high yielding sesame varieties.

The materials for present investigation comprised of 78 newly developed white seeded genotypes selected from F_6 generation of different crosses and four standard check varieties of sesame, *Sesamum indicum* L. A set of 82 entries/varieties of sesame was grown in Randomized Block Design with three replications during *kharif* 2006 at research farm of Agricultural Research Station, Mandor, Jodhpur. Each genotype was sown in five rows of 4 m length following crop geometry of 30 × 15 cm. The data were recorded on five competitive plants taken from each replication for plant height (cm), plant height to first capsule (cm), number of primary branches/plant and number of capsules/plant. The characters like seed yield (kg/ha), test weight (g), oil content (%), days to 50% flowering and maturity were recorded considering whole plot in each replication. The data were subjected to analysis of variance as suggested by Panse and Sukhatme (1985). Genotypic and phenotypic coefficients of variance were estimated as per Burton (1952). Broad sense heritability and genetic advance (GA) as per cent of mean at 5% selection intensity were estimated as per Johnson *et al.* (1955). Clustering was performed by procedure of Ward's minimum variance method (Ward, 1963).

The analysis of variance revealed significant differences among the genotypes for all the characters except oil content, hence not included for further analysis. Wide variability was observed for seed yield i.e., from 250 (RMT 207) to 891 kg/ha (RMT 240) (Table 1). The genotype RT 54 was found earliest in days to 50% flowering (38) and maturity (71 days). The range of plant height was from 95 (RT 54) to 145 cm (RMT 201), plant height to first capsule from 47 (RMT 243) to 93 cm (RMT 194), number of primary branches/plant from 1.0 (RMT 207) to 4.4 (RMT 162), number of capsules/plant from 28 (RMT 207) to 62 (RMT 194) and test weight from 2.44 (RMT 192) to 2.95 g (RMT 236). The high magnitudes of phenotypic as well as genotypic coefficient of variation for seed yield, primary branches/plant and capsules/plant indicated the presence of ample amount of variation for these characters. The high heritability (75-95%) combined with high genetic advance as per cent of mean for seed yield, primary branches/plant, capsules/plant and plant height to first capsule revealed that these characters were controlled by additive gene action, suggesting that selection for these traits would be effective for crop improvement. These

results are in agreement with those reported by earlier workers (Solanki and Gupta, 2004; Babu *et al.*, 2004; Anuradha and Reddy, 2005).

A hierarchical cluster analysis of Ward's minimum variance method produced a dendrogram showing successive fusion of individuals which clearly partitioned the genotypes into eight clusters. The genotypes within each cluster were closer to each other than the genotypes grouped in to different clusters. The maximum intra-cluster distance was observed in cluster VII (13.9) followed by cluster VIII (12.0) and cluster VI (8.9) indicating wide genetic variability within the genotypes of these three clusters (Table 2). The highest inter-cluster distance was observed between cluster V and VIII (94.4) followed by cluster V and VI (69.7) and cluster II and cluster V (58.6), suggesting wide diversity between genotypes of these clusters. Therefore, genotype belonging to these clusters may be used in hybridization programme for improvement of sesame and may give better segregants. The least inter-cluster distance was observed between clusters I and II (8.6) indicating close relationship between the genotypes of these two clusters.

The diversity was also supported by the appreciable amount of variation among the cluster means for different characters (Table 3). The highest cluster mean revealed by cluster V for seed yield, plant height and number of capsules/plant, cluster II for primary branches/plant and cluster III for test weight, while cluster VIII showed minimum cluster means for plant height to first capsule, days to 50% flowering and maturity. These results showed that different clusters genotypes were superior for different characters and genotypes much in use of these characters would offer a good scope of improvement of sesame through rational selection.

Amongst the characters, seed yield contributed maximum towards genetic divergence (38.9%) followed by days to maturity (11.7%), primary branches/plant (11.5%), test weight (10.6%) and number of capsules/plant (10.2%) while characters plant height to first capsule (5.1%) and days to 50% flowering (7.8%) contributed least to genetic divergence (Table 3). These results are in conformity with those reported by Rao (2004 and 2006), and Anuradha and Reddy (2005).

Since varieties with narrow genetic base are more vulnerable to diseases and adverse climatic conditions, therefore, the availability of the genetically diverse genotypes for hybridization programme becomes more important. In the present study the maximum inter-cluster distance observed between cluster V and VIII, cluster V and VII, and cluster II and V, and crosses among genotypes viz. RMT 194, RMT 241, RMT 242, RMT 256, RMT 184, RMT 201, TKG 22 and RT 54 would be resulted into transgressive segregation. Since, seed yield, days to maturity, primary branches/plant, test weight, and capsules/plant contributed maximum towards the divergence, direct selection of these traits help in crop improvement.

Table 1 Estimate of genetic parameters of seed yield and its component traits in sesame

Characters	Mean	Range		Coefficient of variation (%)		Heritability (%)	Genetic advance as % of mean
		Min.	Max.	GCV	PCV		
Seed yield (kg/ha)	571	250	891	25.4	26.0	95	50.9
Days to 50% flowering	42	38	45	3.2	3.6	82	6.0
Days to maturity	80	71	87	2.5	2.7	88	4.9
Plant height (cm)	127	95	145	5.4	6.2	75	9.7
Plant height to first capsule (cm)	59	47	93	8.9	10.3	76	16.0
Primary branches/plant	2.9	1.0	4.4	18.7	20.4	84	35.4
No. of capsules/plant	45	28	62	13.9	15.2	84	26.2
Test weight (g)	2.66	2.44	2.95	3.7	4.1	83	7.0

Table 2 Intra (diagonal) and inter cluster distance among eight clusters in sesame

Cluster	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII
Cluster I	6.6	8.6	10.4	15.1	41.5	13.4	27.3	34.8
Cluster II		5.7	14.9	19.9	58.9	11.4	22.5	28.8
Cluster III			7.2	12.9	38.9	14.4	30.4	38.7
Cluster IV				6.7	36.3	17.4	34.2	23.5
Cluster V					0.0	57.8	69.7	94.4
Cluster VI						8.9	16.4	30.2
Cluster VII							13.9	46.8
Cluster VIII								12.0

Table 3 Cluster means in different clusters and per cent contribution for different characters in sesame

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Contribution to diversity (%)
Seed yield (kg/ha)	611	535	768	681	846	493	328	547	38.9
Days to 50 % flowering	43	43	42	40	40	42	42	39	7.7
Days to maturity	79	80	79	77	78	81	83	75	11.8
Plant height (cm)	128.0	127.8	132.4	118.5	132.3	126.2	129.8	105.8	4.2
Plant height to first capsule (cm)	61.5	56.7	59.9	63.0	92.7	57.8	61.2	48.8	5.2
Primary branches/plant	3.2	3.3	3.0	2.8	2.8	2.7	1.7	2.8	11.5
Capsules/plant	51	45	48	48	62	39	36	38	9.8
Test weight (g)	2.65	2.55	2.79	2.75	2.78	2.72	2.64	2.52	10.5

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Short communication

Rajasthan Til 346 : A high yielding white and bold seeded sesame, *Sesamum indicum* L. variety for National Zone-I of India

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Abstract

A white and bold seeded variety of sesame 'RT 346' was found suitable for cultivation in National Zone-I of India i.e., Rajasthan, Haryana, Punjab, Himachal Pradesh, Gujarat, Western U.P., adjoining parts of Maharashtra and Karnataka.

Keywords: *Sesame, RT 346, white and bold seeded variety*

Sesame is a rich source of protein (24%) and carbohydrates (15%) in addition to good source of quality oil (50%). India is the world leader with the area of 17.5 lakh ha and production of 6.7 lakh tonnes (Anonymous, 2008a). In the country, Rajasthan among the sesame growing states contributes more than 18% in area and production, respectively (Anonymous, 2008a and b).

With a view to develop shining white and bold seeded sesame varieties, breeding efforts were initiated at Agricultural Research Station (Rajasthan Agricultural University), Mandor, Jodhpur. A cross was attempted between RT 127 and HT 24 in the year 1996 and segregating material was handled through pedigree method. As a result of these efforts, the culture, RT 346, was isolated and evaluated for its production potential in *kharif* seasons during 2003 to 2004 along with existing checks of sesame varieties in Randomized Block Design with three replications at different locations of the region. The material was tested in PET (Preliminary Evaluation Trial) and SVT (State Varietal Trial) consisting of 5 m length plot with variable row numbers, i.e., 4 and 6, respectively. The spacing of 30 cm between the rows and 15 cm distance plant to plant was maintained. The agronomic package of practices recommended for the region were followed to reap the good yield.

The RT 346 recorded the mean seed yield (average of 26 trials) of 733 kg/ha as against 611 kg/ha of Pragati and TKG 22 with a yield improvement of 20% over both the check varieties (Table 1).

The morphological features of RT 346 and two check varieties are presented in Table 2. Data indicated that RT 346 is earlier in maturity (83 days) with average plant height of 101.3 cm., high oil content (50%) and more number of capsules/plant (51) with higher oil yield (363 kg/ha) over the checks. The genotype has shining white seed colour suitable for export purpose. Newly selected variety also showed resistance to phyllody and leaf curl viruses and moderately resistance to Macrophomina stem and root rot and Alternaria and Cercospora leaf spot, and capsule borer. In Adaptive trials, RT 346 recorded 19.4% higher seed yield over best adapted variety RT 127 (360 kg/ha) at farmers' fields (data not presented).

Table 1 Summary seed yield (kg/ha) data of coordinated varietal trials

Year of testing	No. of locations	RT 346	Pragati (ZC)	TKG 22 (NC)	Per cent increase over checks	
					Pragati	TKG 22
2005	7	668	568	640	17.6	4.4
2006	8	702	585	543	20.0	29.3
2007	11	797	657	641	21.3	24.3
Mean	-	733	611	611	20	20
Frequency in the top significant group (Pooled for 3 years)			14/26	10/26	5/26	

Table 2 Important characteristics of sesame variety RT 346 compared to checks (2005 to 2007)

Character	RT 346	Check varieties	
		Pragati	TKG 22
Seed colour	White	White	White
Days to 50% flowering	41	42	42
Days to maturity	83	85	83
Plant height (cm)	101.3	98.9	100.2
No. of branches/plant	3.4	3.2	3.5
No. of capsules/plant	51	45	47
1000 seed weight (g)	2.9	2.8	2.9
Oil content (%)	50.0	48.6	49.2
Oil yield (kg/ha)	363	298	309
Macrophomina stem and root rot (%)	9.0	17.1	7.6
Antigastra (% damage)	8.1	14.4	8.1

Looking to its consistence superior performance under rainfed conditions, variety RT 346 was identified in the meeting held during IX Annual Workshop of Sesame and Niger at Nagpur and subsequently released by Central Sub-Committee on Crop Standards, Notification and Release of Variety Vide notification S.O. 449 (E) dated 11.2.2009 for the commercial cultivation in hot and arid ecosystem areas of the National Zone-I, comprising of Rajasthan, Haryana, Punjab, Himachal Pradesh, Gujarat, Western U.P. and adjoining areas of Maharashtra and Karnataka.

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Short communication

Effect of biofertilizer on sunflower, *Helianthus annuus* L.

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Abstract

The pooled analysed data of year revealed that treatment T_9 (50 % Nitrogen + *Azospirillum* treatment) recorded the high seed yield (1685 kg/ha) followed by T_{10} (100 % nitrogen + *Azospirillum* + *Azatobacter* seed treatment) seed yield (1656 kg/ha) but difference was at par (Table 1). Same trend of yield was found in treatment T_8 (50 % N + *Azatobacter* seed treatment) and T_3 (100 % N + *Azospirillum* seed treatment) seed yield 1646 kg/ha and 1627 kg/ha, respectively. Lowest seed yield (785 kg/ha) was obtained in T_1 (control).

Keywords: Sunflower, biofertilizer

Sunflower is an exhaustive oilseeds crop, giving good response to application of fertilizers. Continuous use of chemical fertilizers may, in some situation have detrimental effect on soil properties. Therefore to maintain soil fertility and productivity for long, use of organic manures and biofertilizers is very essential. Thus any attempt made to increase productivity of sunflower can satisfy the need of high oil production. Seed inoculation with *Azospirillum* and use of farm yard manure to sunflower increased its yield as well as oil content (Ram *et al.*, 1992). Keeping these facts in view, an experiment was conducted to study the effect of application of biofertilizers on yield and quality of sunflower. A field experiment was conducted during *kharif* season of 2008 with 11 treatments, 3 replications in a Randomized Block Design at T.C.A., Dholi centre farm which consisted of control (no nitrogen), 50% and 100% recommended doses of nitrogen (80 kg/ha) and seed inoculation with biofertilizer, *Azospirillum* and *Azotobacter* alone and in combination and also integration of these fertilizer with former two recommended doses of nitrogen (Table 1). Seed inoculation was done with *Azospirillum* or *Azotobacter* @ 50 g/kg of seed before sowing. *Azospirillum* or *Azotobacter* culture was added to 150 ml starch solution. This mixture was added to 1 kg of seed and mixed thoroughly. The crop cultivar, KBSH-1 was fertilized with a uniform dose of 50kg P_2O_5 and 30kg K_2O/ha in the form of single super-phosphate and muriate of potash, respectively. The crop was sown with a spacing of 2.2 m × 2.2 m (7 row). . All the cultural practices besides the treatments adopted as per the recommended package of practices. So application of *Azospirillum* and *Azotobacter* separately or jointly with 50% N (of recommended dose of N) can save the 50% nitrogen for higher seed yield of sunflower. These findings are in line with those of Kumari *et al.* (2004).

Table 1 Seed yield, oil content and oil yield of sunflower as influenced by different biofertilizer treatments

	Treatment	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
T_1	No nitrogen (control)	785	40.2	315
T_2	50 % recommended dose of nitrogen	1075	42.0	451
T_3	100 % recommended dose of nitrogen	1627	39.3	639
T_4	Azospirillum seed treatment only	815	40.5	330
T_5	*Azotobacter* seed treatment only	885	40.2	355
T_6	*Azospirillum Azotobacter* + *Azotobacter*	890	39.6	352
T_7	50% Nitrogen + *Azospirillum* treatment	1600	40.4	646
T_8	50% Nitrogen + seed treatment	1646	39.8	655
T_9	50% nitrogen + *Azospirillum* + *Azotobacter* seed treatment	1685	40.0	674
T_{10}	100% Nitrogen + *Azospirillum* + *Azotobacter* seed treatment	1656	39.2	649
T_{11}	75% Nitrogen + *Azospirillum* + *Azotobacter* seed treatment	1608	39.0	627
	SEm ±	23	0.5	5
	CD (P=0.05)	81	1.7	15

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Short communication

Inter-relay cropping of castor in greengram under irrigated condition

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Abstract

A field experiment was conducted on loamy sand soils during *kharif* seasons of 2006-07 to 2008-09 to study the effect of inter-relay cropping of castor in greengram under irrigated condition. The results showed that sole castor (4030 kg/ha) remaining comparable with castor intercropped with greengram (1:1) with simultaneous sowing (3924 kg/ha) gave significantly higher yield than castor relay intercropped with greengram staggered sowing at 15, 30, 45 DAS of greengram and harvest of greengram. Simultaneous sowing of castor in greengram gave higher castor equivalent yield, net realization and BCR as compared to delayed sowing. Seed yield of castor was decreased with extent in sowing period. Economics of different treatments indicated that the net realization and B : C ratio from both the crops were higher when the castor + greengram were seeded simultaneously. Sowing of castor after harvest of greengram is found not beneficial.

Keywords: Intercropping, castor

Castor is an important non-edible industrial oilseed crop of North Gujarat. During 2007-08 the state occupied the top position in area (3.58 lakh ha), production (7.08 lakh tonnes) and productivity (1978 kg/ha). However, it is ideally suited for intercropping system by virtue of its drought tolerance, perenniating nature, branching habit and indeterminate penology (Hegde and Sudhakara Babu, 2002). To study the influence of staggered sowing of castor in greengram stand as inter cropping the present study was undertaken.

Field experiment was conducted at the Main Castor-Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar, Gujarat during *kharif* seasons of 2006-07 to 2008-09. The soil of experimental plot was loamy sand in texture with pH 7.8. It was low in organic carbon (0.12%) and available nitrogen (157 kg/ha), medium in available phosphorus (50) and available potash (243). The experiment comprised of six treatments conducted in Randomized Block Design with four replications (Table 1). Castor hybrid GCH-7 and greengram variety GM-4 were selected as test verities. A recommended dose of fertilizers was applied to both the crops. Greengram was sown at 45 cm row spacing in sole treatment while in intercropping, it was sown at 120 cm row spacing. Castor was grown at 120 cm x 60 cm both as sole and in intercropping.

Table 1 Seed yield of castor and castor equivalent yield (kg/ha)

Tr. No	Seed yield of castor (kg/ha)				Castor equivalent yield (kg/ha)				BCR
	2006-07	2007-08	2008-09	Pooled	2006-07	2007-08	2008-09	Pooled	
1	4039	4068	3521	3876	4039	4068	3521	3876	2.63
2	3963	3962	3589	3838	4707	4838	4378	4641	3.01
3	3499	3405	2872	3259	4339	4451	3722	4170	2.85
4	3362	3171	2766	3100	4262	4332	3730	4108	2.79
5	3195	2485	1732	2471	4099	3578	2726	3468	2.32
6	2729	2154	1382	2088	4344	4303	3421	4023	2.35
SEm±	178	128	181	135	208	140	157	152	-
CD (P=0.05)	535	385	546	425	NS	421	475	431	-
CV (%)	10.3	8.0	13.71	10.1	9.7	6.6	8.8	13.0	-

In this study, the influence of staggered sowing of castor in greengram stand as intercropping has been evaluated. The results showed that sole castor remaining comparable with castor intercropped with greengram (1:1) with simultaneous sowing gave significantly higher seed yield than castor relay intercropped with greengram staggered sowing at 15, 30, 45 DAS of greengram and harvest of greengram. With delay in castor sowing at fortnightly intervals, there was a drastic reduction in seed yield. The data further indicated that maximum castor equivalent yield from both the seasons was recorded when castor was intercropped in greengram (1:1) with simultaneous sowing followed by castor intercropped in greengram (1:1) and sown after 15 DAS of greengram. Economics of different treatments indicated that the net realization and B : C (3.01) ratio from both the crops were higher when the castor + greengram were seeded simultaneously. Similar results were reported by Patel *et al.* (2007), Reddy *et al.* (2008) and Lila Rani (2008). Sowing of castor after harvest of greengram is found not beneficial.

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Short communication

Study on intercropping of castor, *Ricinus communis* L. under irrigated condition

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Abstract

Castor and companion crops were sown at 120 cm x 60 cm row x plant spacing respectively at Mandor, Rajasthan. The castor yield was not reduced significantly by raising intercrops. Sole castor produced maximum seed yield of 3694 kg/ha closely followed by castor + greengram 1:1, castor + moth bean 1:1. The castor seed equivalent yield recorded with castor + greengram 1:1 (4531 kg/ha) was 837 kg/ha higher over sole castor. Corresponding increase due to castor + moth bean 1:2 system was 639 kg/ha. Castor + sesame intercropping system in 1:1 and 1:2 ratios was not found effective as seed equivalent yield, net return and B:C ratio were not influenced remarkably due to adoption of this system.

Keywords: Castor, intercropping, seed equivalent yield

Rajasthan ranks second in terms of castor acreage and production (104.7 thousand ha and 159.4 thousand tonnes, respectively) after Gujarat where intercropping of pulses and short strature crops with castor is very common (Anonymous, 2009). Castor growing areas in Rajasthan are characterized with frequent drought in light sandy soils. In western part of state, continuous availability of electricity using wind mills and good quality water through bore well technology has opined new era for castor cultivation. Therefore, studies on intercropping of castor under irrigated crop culture were planned.

The experiment was conducted at Agricultural Research Station, Mandor (Jodhpur) in three consecutive seasons 2005-06, 2006-07 and 2007-08. The soil of the site was loamy sand having pH 8.2 with low available nitrogen (149 kg/ha), medium available phosphorus (38 kg/ha) and potassium (380 kg/ha). The experiment was laid out in Randomized Block Design with seven treatments and replicated three times (Table 1). Castor crop was sown at 120 and 60 cm spacing (row x plant) in field. In between two rows of castor one or two rows of intercrop (as per treatment) were sown at 30 x 10 cm row x plant spacing. The net plot size was 4.8 m x 4.8 m. Castor as well as all the intercrops were sown in the first fortnight of July every season with the on set of rains. Crop was initially kept rainfed but after withdrawal of rains, it was irrigated 8 times at 18-20 days interval. The total rainfall received during the seasons 2005-06, 2006-07 and 2007-08 was 227, 254 and 163 mm, respectively. Castor was fertilized with 80 kg N, 50 kg P_2O_5/ha whereas greengram and mothbean according to row ratio were fertilized with 20 kg N and 20 kg P_2O_5/ha. Sesame was fertilized with 25 kg N and 20 kg P_2O_5/ha. In castor, half nitrogen and full phosphorus was applied as basal dose and remaining nitrogen was applied in two equal splits at 35 and 90 days after sowing with irrigation water. Greengram, sesame and moth bean took 80, 85 and 70 days, respectively to mature whereas castor was harvested through 6 pickings at one month interval starting from 90 DAS. Seed yield of component crops were converted into castor equivalent seed yields, considering the prevailing prices of the produce during the year.

The results showed that growth attributes, seed yield and oil content of castor was not influenced significantly by intercropping system providing compatibility of the companion crops in the system. However, the highest seed yield was recorded in sole castor (3694 kg/ha) closely followed by castor + greengram 1:1 (3593 kg/ha) and castor + mothbean 1:1 (3525 kg/ha) system. Giridhari and Giri (1991) obtained the highest seed yield of intercropped castor (1018 kg/ha) at 90 cm with one row of greengram with seed yield of 200 kg/ha. The castor seed equivalent yield recorded with castor + greengram 1:1 and 1:2 systems was significantly more by 22.7 and 21.1%, respectively when compared with sole castor. Similarly, castor + mothbean 1:1 and 1:2 systems also increased castor seed equivalent yield by 16.1 and 17.3%, respectively when over sole castor. The castor seed equivalent yield was not influenced significantly when sesame was intercropped with castor. Sesame as a intercrop did not perform well because during early phase castor and sesame both grows vertically and competed for space and light. Whereas, greengram and mothbean adjusted horizontally in the available space between two rows of castor and produced bumper seed yield. Being legume crop, moth bean and greengram also benefitted castor which remained in the field for 150-160 days after harvest of both these crops. Prasad *et al.* (1993) reported that intercropping system decreased leaching of N, P and

K and increased soil fertility compared with pure stands of castor. Singh and Singh (1988) also reported similar results.

The spikes/plant and 100-seed weight of castor was reduced significantly by 2.8/plant and 2.7 g, respectively when sesame was intercropped with castor in 1:1 ratio. Castor seed yield was found to be reduced when intercropped with sesame, sorghum and maize (Gupta and Rathore, 1993). Economic evaluation reveal that castor + greengram in 1:1 ratio is the best option as it provided maximum net return and B:C ratio. Castor + greengram 1:1 ratio increased net compared to sole castor. Gupta and Rathore (1993) recorded maximum monetary advantage of Rs. 3907/ha from castor + greengram intercropping system followed by castor + blackgram. Castor + mothbean 1:1 and 1:2 are other options which increased the net return over sole castor. Increases in net return due to castor + sesame 1:1 and 1:2 ratios were not remarkable. The B:C ratios recorded with castor + sesame 1:1 and 1:2 systems were reduced to 3.08 and 3.01, respectively compared with maximum ratio of 3.58 observed with castor + greengram in 1:1 ratio.

Table 1 Seed yield, growth and yield attributes of castor as influenced by intercropping under irrigated conditions (Pooled mean of 3 reasons)

Treatment	Plant stand ('000 ha)	Plant height (cm)	Nodes upto primary raceme	100-seed weight (g)	Raceme length (cm)	Spikes/ plant	Intercrop mean seed yield (kg/ha)	Castor seed equivalent yield (kg/ha)	Castor seed yield (kg/ha)	Oil content (%)	B:C ratio
Sole castor	13.1	61	15	27	41	18	-	3694	3694	50.3	3.20
Castor + Mungbean (1:1)	13.0	57	14	26	40	18	546	4531	3593	49.5	3.58
Castor + Mungbean (1:2)	13.1	57	13	26	40	16	606	4472	3429	49.7	3.44
Castor + Sesame (1:1)	13.5	66	15	24	38	15	280	3829	3356	48.0	3.08
Castor + Sesame (1:2)	13.1	64	15	25	37	15	321	3870	3332	48.9	3.01
Castor + Mothbean (1:1)	13.5	58	13	26	39	19	573	4287	3525	49.1	3.40
Castor + Mothbean (1:2)	13.4	62	14	26	42	18	629	4333	3491	49.7	3.37
SEm±	0.3	3.8	0.8	0.8	2.1	1.3	-	254	128	0.9	-
CD (P=0.05)	NS	NS	NS	2.3	NS	3.8	-	NS	NS	NS	-
CV (%)	3.2	14.2	10.3	1.2	9.6	3.6	-	13.5	13.8	1.2	-

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Short communication

Efficacy of new insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.)

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Abstract

Efficacy of newer insecticides was studied against mustard aphid, *Lipaphis erysimi* (Kalt.) and their effect on *Coccinella septumpunctata* was also recorded at Pilibhit (UP) during 2007-08 on Indian mustard. The insecticides used are acetamiprid 20 SP (125 g/ha) and imidachloprid 17.8 SL (150 ml/ha). Acetamiprid 20 SP (125 g/ha) proved as the best insecticide followed by acephate, thiamethoxam, imidacloprid, profenofos, dimethoate and oxydemeton methyl for the management of aphids. Thiamethoxam was found as the safer insecticide to the coccinellids.

Keywords: *Brassica juncea, Lipaphis, Coccinellid,* efficacy

About three dozen insect pests have been found infesting mustard crop in India of which the mustard aphid, *Lipaphis erysimi* (Kalt.) is the key pest (Upadhyay *et al.*, 1999). Inspite of having certain limitations, the use of insecticides still remains the practically and economically viable solution to combat the aphids. The use of older insecticides causes sudden decrease in the number of natural enemies also. Therefore, the present study was undertaken to test some newer insecticides against mustard aphid and their safety to its predators on mustard crop.

An experiment was conducted at farmers' field in the Terai region of Uttar Pradesh in Pilibhit district during *rabi*, 2007-08 in Randomized Block Design with three replications in a net plot size of 15 m^2. Seven insecticides and a control (untreated) were tested on the crop, Indian mustard. Insecticides were sprayed once when the aphids reached economic threshold level (ETL 28/10 cm shoot). Mortality of aphids and coccinellids was recorded after 1, 2, 3, 7 and 10 days of spray.

All treated plots had drastic reduction in aphid population as compared to untreated control (Table 1). Acetamiprid was the most effective insecticide. Ali and Khan (2008) also found imidacloprid more effective than dimethoate and oxydemeton methyl against aphids. Thiamethoxam was the safest insecticide against coccinellids followed by acetamiprid and imidacloprid. Oxydemeton methyl and dimethoate caused 100% mortality of predators. Present results are in agreement with Kannan *et al.* (2004). Highest C:B ratio of 2.15 was found with acetamiprid followed by acephate and thiamethoxam.

Table 1 Effect of various insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.)

Treatment	dose/ha	Mean number of aphids/shoot						No. of lady bird beetles/shoot (10 days after spray)	Yield (kg/ha)	C:B ratio (Rs.)
		Before spray	Days after spray							
			1	2	3	7	10			
Thiamethoxam 25 WDG	100 g	173	112.3 (34.9)	47.7 (72.4)	14.6 (91.8)	5.3 (96.9)	0.0 (100.0)	5.7 (-21.4)	1691	2.08
Profenofos 50 EC	1000 ml	168	123.6 (26.0)	50.7 (69.7)	21.3 (87.2)	9.67 (94.2)	4.3 (97.4)	0.0 (100.0)	1449	1.77
Imidacloprid 17.8 SL	150 ml	179	119.3 (33.2)	48.3 (72.9)	13.3 (92.5)	3.7 (97.9)	0.0 (100.0)	5.3 (0.0)	1657	2.06
Dimethoate 30 EC	1000 ml	160	114.6 (28.18)	53.7 (66.4)	21.6 (86.4)	8.3 (94.7)	4.5 (97.1)	0.0 (100.0)	1319	1.61
Acetamiprid 20 SP	125 g	159	108.6 (31.5)	46.3 (70.1)	12.3 (92.2)	4.3 (97.2)	0.0 (100.0)	6.3 (0.0)	1730	2.15
Oxydemeton methyl 25 EC	1000 ml	165	128.6 (21.8)	64.7 (60.7)	23.6 (85.6)	11.6 (92.9)	4.7 (97.2)	0.0 (100.0)	1246	1.52
Acephate 75 SP	500 g	167	107.6 (35.4)	44.7 (73.2)	8.3 (95.0)	2.3 (98.6)	0.0 (100.0)	6.3 (-11.6)	1723	2.13
Control	-	174	195.3 (11.8)	219.3 (-25.6)	279.3 (-59.9)	311.3 (-78.2)	389.7 (-123.1)	10.3 (-121.2)	873	1.10
CD (P=0.05)		NS	15.5	16.1	16.1	20.7	19.4	5.1	291	

Figures in parentheses are per cent mortality.

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Short communication

Efficacy of bioagents and organic amendments against *Macrophomina phaseolina* (Tassi) causing root rot of sesame

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Abstract

Studies indicated that use of *Trichoderma viride* (seed treatment) 4 g/kg, soil application 5 kg/ha with FYM managed *Macrophomina phaseolina* causing root rot in sesame.

Keywords: *Macrophomina phaseolina*, root rot, sesame

Sesame, *Sesamum indicum* L., is the third major oilseed crop of India. Root rot caused by *Macrophomina phaseolina* (Tassi.) Goid, is one of the most serious diseases of sesamum causing 42-45% yield losses. Biological control methods have shown promise in managing this pathogen, hence the present study was undertaken.

M. phaseolina was isolated from root rot infected plants of sesame from farmers' field of Vallampadugai Village, Cuddalore District of Tamil Nadu and pure culture was maintained on PDA slants at 4°C. Pure culture of *M. phaseolina* was inoculated on PDA medium in petriplates and incubated at 25±1°C for 5 to 7 days. *M. phaseolina* was multiplied on autoclaved sorghum seeds at 25±1°C for 12 days and the final population was adjusted to maintain 10^6 cfu/g preparation.

Powdered, sieved and sterilized (1.4 kg/cm pressure, 2 hr for 3 consecutive days) silky clay soil incorporated with FYM @ 12.5 t/ha was filled in earthern pots (30 cm diameter) @ 6 kg/pot and inoculum of *M. phaseolina* was incorporated earlier (50 g/kg of soil and it was irrigated for 7 days and allowed the pathogen to multiply). Seeds were treated with talc based formulation of antagonist @ 4 g/kg of seed and its combination with FYM as soil application was done. The amendment was tested in combination with seed 4 g talk based formulation of *T. viride*/kg of seed and soil application of *T. viride* 5 kg/ha on 45 DAS. For comparison carbendazim @ 2 g/kg was used. Soil without treatment served as control. Three replications were maintained for each treatment.

All the treatments significantly increased both root and shoot length of plant over control at 60, 120 days of observation. Soil application of FYM combined with *T. viride* application (seed + soil of on 45 DAS) registered highest root and shoot length of 14.03 and 90.50 cm on 120 DAS followed by soil application of FYM + *T. viride* (seed + soil). Similar observations were made in the field trial experiment (Table 2). These findings are in agreement with the findings of Change *et al.* (1986), Ghisalberti *et al.* (1990) and Ousley *et al.* (1994). Incidence of root rot was recorded at regular intervals and the least root rot incidence of 9.24% was observed with FYM combined with *T. viride* (seed + soil + soil on 45 DAS) application, seed treatment with *T. viride* and carbendazim alone reduced the root rot incidence by 25 and 22.50%, respectively over control (51.45%) (Table 1). All the treatments significantly increased the drymatter production of plants over untreated control. The maximum drymatter of 4.02 g/plant was recorded in pots applied with FYM combined with application of *T. viride* (seed and soil + soil on 45 DAS) followed by soil application of FYM + *T. viride* (seed + soil). The untreated control registered the least drymatter production of 3.14 g/plant. Management of *M. phaseolina* using organic amendments along with bioagents was reported by Jamadar and Desai (1996) and Desai *et al.* (1997). Application of FYM combined with *T. viride* (seed + soil + soil on 45 DAS) recorded the least dry root rot incidence and maximum vigour index of sesame.

Table 1 Effect of bioagents and organic amendments against *M. phaseolina* (Pod culture)

Treatment	Root length (cm)	Shoot length (cm)	% root rot incidence	Drymatter production (g/plant)
T. viride (ST) 4 g/kg	10.94	67.70	25.00	3.52
T. viride (SA) 5 kg/ha	12.74	73.11	18.12	3.55
T. viride 4 g/kg (ST) + *T. viride* 5 kg/ha on 45 DAS	13.00	75.00	15.00	3.71
FYM (SA) + T_1	13.11	83.40	12.08	3.86
FYM (SA) + T_2	13.63	87.41	11.04	3.91
FYM (SA) + T_3	14.63	90.50	9.24	4.02
Carbendazim 2 g/kg (ST)	11.10	67.70	22.50	3.51
Control	10.03	50.90	51.45	3.14
SED±	1.16	0.32	-	-
CD (P=0.05)	2.55	0.71	-	-

Table 2 Effect of bioagents and organic amendments against *M. phaseolina* (Field trial)

Treatment	Root length (cm)	Shoot length (cm)	% root rot incidence	Drymatter production (g/plant)
T. viride (ST) 4 g/kg	10.89	68.01	24.00	3.02
T. viride (SA) 5 kg/ha	12.68	72.21	16.12	3.46
T. viride 4 g/kg (ST) + *T. viride* 5 kg/ha on 45 DAS	12.52	77.02	14.52	3.59
FYM (SA) + T_1	13.17	85.61	10.94	3.72
FYM (SA) + T_2	13.59	89.01	10.96	3.82
FYM (SA) + T_3	13.39	85.50	9.12	3.92
Carbendazim 2 g/kg (ST)	11.10	67.69	21.22	3.49
Control	9.99	45.99	51.45	3.14
SED±	1.15	0.30	-	-
CD (P=0.05)	2.54	0.69	-	-

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Short communication

Multiple resistance sources against major diseases and pests of safflower, *Carthamus tinctorius* L.

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Abstract

From the above study, it could be concluded that the three genotypes of safflower *viz.*, GMU-5097, GMU-5133 and GMU-7017 recorded moderately tolerant reaction to *Alternaria* leaf spot, resistant reaction to Fusarium wilt and tolerant reaction to aphid.

Keywords: Safflower, multiple resistance, pests

Safflower (*Carthamus tinctorius* L.) is an important rabi oilseed crop, damaged by a number of insect pests and diseases of which aphid, *Uroleucon compositae* and *Fusarium oxysporum* f.sp. *carthami* are key pests (Singh *et al.*, 1999 and Anonymous, 2003). Fusarium infects the plants right from seedling stage to flowering and can cause upto 100% yield loss under severe incidence. Most of the earlier workers tried to identify resistant sources separately to *Alternaria* leaf spot of safflower (Lukade and Indi, 1985), safflower wilt (Mehetre *et. al.*, 2004) and safflower aphids (Rathore and Pathak, 1982). The present investigations were, therefore, undertaken to screen the safflower genotypes for isolating multiple resistant/tolerant sources to *Alternaria* leaf spot, *Fusarium* wilt and aphid.

The most promising 50 safflower germplasm accessions supplied by Project Director, Directorate of Oilseeds Research, Hyderabad were used for screening against *Alternaria* leaf spot, *Fusarium* wilt and aphid for isolating multiple resistant/tolerant sources. The accessions were grown in single row of 4 m length with the spacing of 45 x 20 cm with randomized block design having two replicates. The variety Nira was used as a susceptible check which was sown after every 5th row of the test material and cultivar Bhima was used as a local check. The inoculum load of *Fusarium oxysporum* f. sp. *carthami* in the wilt sick plot was 3-4 x 10^4 cfu/g of soil. The wilt incidence was recorded at 15, 30, 45, 60, 75 and 90 days after sowing. The results were again confirmed by screening same set of germplasm during 2004-05 in the wilt sick plot.

Subsequently, the same set of germplasm accessions was screened during *rabi* season of 2003-04 and 2004-05 against *Alternaria* leaf spot and aphid. For *Alternaria* leaf spot, these accessions were screened under natural field conditions in a single row of 4 m length replicated twice using HUS-305 as a tolerant check, Manjira as a susceptible check, Bhima and Phule Kusuma as local checks. Crop was sown in second fortnight of August to create natural epiphytotics of the disease. The conidial suspension was sprayed on the crop frequently in the evening hours. On the following day, the crop was sprayed with water to provide favourable humidity for infection. Five randomly selected plants from each plot were scored for the disease reaction at 15 days interval using 1-9 scale (Anonymous, 2006). The per cent disease intensity was calculated. Same germplasm accessions were sown in the first fortnight of November for screening against aphid using cultivar CO-1 as a susceptible check, Bhima and Phule Kusuma as local standard checks. The observations on aphid count were recorded on 5 cm apical twig plant-1 on five randomly selected plants.

Out of 50 germplasm only five genotypes recorded tolerance to the alternaria disease (disease intensity below 40%) under such a high disease pressure (77.8% on susceptible check, Manjira) of *Alternaria* leaf spot and tolerant check, HUS-305 had only 33.3% disease incidence. These results are in conformity with Indi *et al.* (2004). Out of 50 genotypes screened against wilt in sick plot, five germplasm accessions *viz.*, GMU-1630, GMU-3955, GMU-5097, GMU-5133 and GMU-7017 found free from wilt successively for two years, whereas six accessions *viz.*, GMU-332, GMU-1633, GMU-2020, GMU-3256, GMU-3944, and GMU-7188 recorded moderately resistant reaction to wilt showing less than 10% wilting. The genotypes *viz.*, GMU-174, GMU-1087 and GMU-2936 recorded tolerant reaction (11-20%) to wilt. Rest of the genotypes along with local checks Bhima and Phule Kusuma felt under susceptible to highly susceptible category. The susceptible check Nira which was sown after every fifth row of test material recorded 95.1% average wilting. These results are in conformity with Mehetre *et al.* (2004).

Among the 50 germplasm screened, only two entries (GMU-5134 and GMU-5136) exhibited highly tolerant (1.0) foliage drying grade against aphids, eight entries *viz.*, GMU-4480, 4484, 5097, 5130, 5133, 5137, 5142 and 7017

possessed tolerant (2.0) foliage drying grade, 26 genotypes were moderately tolerant (3.0), whereas rest of the entries were categorized as susceptible (4.0) to the aphid reaction. The local check Bhima and Phule Kusuma recorded moderately tolerant (3.0) foliage drying grade, whereas the susceptible check CO-1 exhibited highly susceptible (5.0) foliage drying grade.

Table 1 Screening of safflower genotypes for multiple resistance against pest and diseases (2003-04 and 2004-05)

Entry	*Alternaria* leaf spot		*Fusarium* wilt		Aphid		Entry	*Alternaria* leaf spot		*Fusarium* wilt		Aphid	
	DI grade (1-9 scale)	PDI	Incidence (%)	Category	Foliage drying grade	Category		DI grade (1-9 scale)	PDI	Incidence (%)	Category	Foliage drying grade	Category
GMU-174	6.6	73.3	20.0	T	3.0	MT	GMU-5133	3.4	37.8	0.0	I	2.0	T
GMU-178	6.6	73.3	33.3	S	3.0	MT	GMU-5134	6.6	73.3	33.3	S	1.0	HT
GMU-332	6.6	73.3	9.1	MR	3.5	S	GMU-5135	5.4	60.0	60.0	HS	3.0	MT
GMU-589	6.2	68.9	80.0	HS	3.0	MT	GMU-5136	6.2	68.9	100	HS	1.0	HT
GMU-1087	7.0	77.8	11.1	T	3.0	MT	GMU-5137	6.2	68.9	64.3	HS	2.0	T
GMU-1251	5.4	60.0	38.5	S	3.0	MT	GMU-5141	5.4	60.0	100	HS	3.0	MT
GMU-1394	5.8	64.4	87.5	HS	4.0	S	GMU-5142	6.6	73.3	53.3	HS	2.0	T
GMU-1628	5.4	60.0	28.6	S	3.0	MT	GMU-5143	7.0	77.8	33.3	S	3.0	MT
GMU-1630	6.6	73.3	0.0	I	4.0	S	GMU-5144	5.8	64.4	42.9	S	4.0	S
GMU-1633	5.8	64.4	5.3	MR	3.5	S	GMU-5145	5.8	64.4	76.5	HS	4.0	S
GMU-1811	7.0	77.8	35.3	S	4.0	S	GMU-5146	5.8	64.4	33.3	S	3.0	MT
GMU-2020	7.0	77.8	8.3	MR	2.5	MT	GMU-5147	3.4	37.8	94.4	HS	3.0	MT
GMU-2130	5.8	64.4	36.4	S	3.0	MT	GMU-5149	5.0	55.5	25.0	S	4.0	S
GMU-2775	7.4	82.2	100.0	HS	3.0	MT	GMU-6299	5.8	64.4	100	HS	3.0	MT
GMU-2936	6.2	68.9	14.3	T	3.0	MT	GMU-6401	6.6	73.3	69.2	HS	3.0	MT
GMU-3256	5.8	64.4	6.7	MR	3.0	MT	GMU-7017	3.0	33.3	0.0	I	2.0	T
GMU-3944	6.2	68.9	8.3	MR	3.0	MT	GMU-7172	5.0	55.6	90.0	HS	3.0	MT
GMU-3955	5.8	64.4	0.0	I	3.5	S	GMU-7152	5.4	60.0	92.9	HS	4.0	S
GMU-4480	6.6	73.3	80.0	HS	2.0	T	GMU-7186	6.6	73.3	54.5	HS	3.0	MT
GMU-4484	6.6	73.3	83.3	HS	2.0	T	GMU-7187	5.8	64.4	75.0	HS	3.5	S
GMU-4608	5.4	60.0	43.8	S	3.0	MT	GMU-7188	3.0	33.3	8.3	MR	4.0	S
GMU-4625	5.4	60.0	33.3	S	3.0	MT	GMU-7191	7.0	77.8	100	HS	4.0	S
GMU-4609	6.2	68.9	100.0	HS	4.0	S	Manjira (SC)	7.0	77.8	-	-	-	-
GMU-5097	2.6	28.9	0.0	I	2.0	T	Nira (SC)	-	-	95.1	HS	-	-
GMU-4627	5.8	64.4	66.7	HS	3.0	MT	CO-1 (SC)	-	-	-	-	5.0	HS
GMU-5130	5.4	60.0	66.7	HS	2.0	T	HUS-305(TC)	3.0	33.3	8.3	MR	-	-
GMU-5131	5.4	60.0	81.8	HS	3.0	MT	Bhima (LC)	3.0	37.8	57.3	HS	3.0	MT
GMU-5132	5.8	64.4	81.8	HS	3.0	MT	P.Kusuma(LC)	3.4	37.8	57.4	HS	3.0	MT

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Short communication

Seed mycoflora associated with castor, *Ricinus communis* L. and their effect on germination

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Abstract

Castor (*Ricinus communis* L.) seeds were analyzed for mycoflora and germination. Forty seven fungal species belonging to seven genera were isolated from 185 seed samples of castor. The seed samples were collected from different agro climatic regions of Karnataka during *kharif*, 2006-07. Seeds were also collected from fields (49) farmers (73), retail shops (16) and APMC markets (47). These seeds were subjected for seed health test by standard blotter method (SBM). During the two years 20 samples showed higher incidence of pathogens, and these samples were tested by potato dextrose agar (PDA), water agar (WA) and 2,4-Dichloro phenoxy acetic acid (2,4-D) methods. Fields and farmers samples showed a higher incidence of pathogens than others. Among the samples screened, seeds collected from Bangalore-rural and Mysore districts showed highest incidence of pathogens than other districts. Important fungal species are *Fusarium oxysporum* f.sp. *ricini* (23-100%), *Alternaria ricini* (2-22%), *A. alternata* (0-10%), *Curvularia lunata* (6-32%), *Macrophomina phaseolina* (10-18%) *Sclerotinia sclerotiorum* (4-20%), *Cladosporium herbarum* (2-10%) and *Chaetomium globosum* (4-29%), *Botryodiplodia acerina* (0-5%), *Stachybotrys chartarum* (6-10%), *Aspergillus ochraceus* (1-31%), *A. niger* (2-20%), *A. flavus* (1-28%), *A. versicolor* (5-12%) and *Rhizopus stolonifer* (1-9%). These 15 fungi were predominant on castor beans and were isolated from normal, abnormal, ungerminated and rotted seeds. Among the seed health test methods, standard blotter method (SBM) proved superior over other methods. Heavily infected seeds did not germinate. The associated fungi reduced the germination.

Keywords: Castor seed, mycoflora, germination, seed health test

Castor is one of the important non edible oilseed crop. Castor is cultivated over on area of 20161 ha with a production 17493 tones and productivity 193 kg/ha in Karnataka (Anonymous, 2006). The important diseases of castor crop are The important diseases are wilt (*Fusarium oxysporum* f.sp. *ricini*), leaf spot and blight (*Alternaria ricini*), Cercospora leaf spot (*Cercospora ricinella*), root rot, stem rot and charcoal rot (*Macrophomina phaseolina*), seedling blight (*Phytophthora parasitica*), capsule rot (*Cladosporium oxysporum*), fruit rot and gray rot (*Botrytis ricini*), rust (*Melamspora ricini*), powdery mildew (*Leveillula taurica*), phyllosticta leaf spot (*Phyllosticta bosensis*), angular leaf spot (*Botrytis* sp.,) damping off (*Phythium aphanidermatum*) (Rangaswamy and Mahadevan, 2005). The aim of the present study was to investigate the incidence of fungi associated with seeds of castor their frequency and their effect on germination.

Seed samples of castor (185) were collected from different agro climatic regions of Karnataka during *kharif*, 2006 and 2007 (Table 1) fields, farmers, retail shops and APMC markets. The collected seeds were stored in cloth bags at room temperature 25±2°C for further investigation. Selected seed samples were subjected for standard blotter method (SBM), Potato dextrose agar (PDA), water agar (WA) and 2,4-Dichloro phenoxy acetic acid (2,4-D) methods.

The seed mycoflora were analysed by following methods

Standard blotter method (SBM): Four hundred seeds were surface sterilized with 0.2% sodium hypochloride or mercuric chloride ($HgCl_2$) solution for 2 to 3 minutes, at the rate of 10 seeds in each Petriplate lined with moist blotter papers. The plates were incubated at a room temperature 25±2°C under alternating cycles of NUV 12 hrs light and darkness for seven days (ISTA, 1976).

Potato dextrose agar (PDA): Four hundred seeds were surface sterilized with 0.2% sodium hypochloride solution for 2 to 3 minutes and plated on sterile Petri plates containing Potato dextrose agar (PDA). Ten seeds per plate were incubated 25±2°C for seven days.

Water agar (WA): Four hundred seeds were surface sterilized with 0.2% sodium hypochloride solution for 2 to

3 minutes and plated on sterile glass Petri plates containing (2.5%: 12.5 g in 1000 ml of distilled water) water agar medium. Ten seeds per plate were incubated at 25±2°C room temperature for seven days (ISTA, 1976).

2,4-D method: The blotter paper discs were dipped in 0.2% of 2,4-Dichloro phenoxy acetic acid solution. Ten seeds were placed equidistantly on moist blotter discs using sterilized forceps in a laminar air flow. Then the plates were incubated at 25±2°C for room temperature for seven days.

Table 1 Seed mycoflora of castor in different seed health test methods during *kharif*, 2006

Place of collection	Methods	Germ (%)	Seed mycoflora (%)														
			Fo	Ar	Aa	Cl	Mp	Ch	Cg	Sc	Ss	Ba	Ao	Af	An	Av	Rs
Jalahalli	SBM	1.0	97.0	19.0	-	-	11.0	2.0	16.0	6.0	4.0	-	19.0	1.0	2.0	-	-
	PDA	33.0	41.0	15.0	10.0	-	12.0	-	12.0	5.0	-	-	-	-	-	14.0	-
	WA	7.0	22.0	-	-	-	-	-	-	-	-	-	2.0	3.0	-	-	1.0
	2,4-D	-	6.0	1.0	-	-	-	10.0	6.0	-	-	-	-	5.0	-	-	-
Yeshvantha pura	SBM	8.0	22.0	16.0	5.0	6.0	-	12.0	-	-	-	-	10.0	16.0	8.0	4.0	-
	PDA	40.0	9.0	10.0	2.0	-	-	-	-	-	-	-	-	11.0	1.0	-	-
	WA	30.0	2.0	6.0	10.0	11.0	-	-	-	-	-	-	4.0	8.0	-	-	-
	2,4-D	-	11.0	9.0	12.0	5.0		13.0	-	-	-	-	17.0	4.0	-	-	-
Nelamagala	SBM	40.0	44.0	22.0	-	6.0	14.0	10.0	22.0		13.0	5.0	25.0	-	-	-	-
	PDA	27.0	23.0	10.0	5.0	9.0	11.0	6.0	-		10.0	11.0	28.0	21.0	23.0	-	25.0
	WA	76.0	9.0	9.0	4.0	-	-	14.0	-		-	-	15.0	10.0	.11.0	18.0	9.0
	2,4-D	-	17.0	14.0	10.0	-	10.0	19.0	-		-	-	51.0	21.0	22.0	19.0	20.0
Dudda	SBM	55.0	44.0	22.0	-	8.0	-	-	1.0	9.0	-	-	22.0	22.0	20.0	11.0	-
	PDA	29.0	19.0	10.0	-	-	-	-	-	-	-	-	-	4.0	-	1.0	9.0
	WA	81.0	9.0	4.0	1.0	-	-	-	-	-	-	-	30.0	9.0	10.0	2.0	-
	2,4-D	-	22.0	10.0	5.0	-		8.0	8.0	-	-	-	-	14.0	15.0	3.0	15.0
Anekal	SBM	53.0	23.0	16.0	-	3.0	18.0	5.0	17.0		20.0	-	29.0	03	-	-	-
	PDA	31.0	15.0	9.0	-	-	-	-	8.0		14.0	2.0	17.0	5.0	6.0	-	11.0
	WA	41.0	2.0	-	-	-	-	-	-		-	5.0	2.0	-	1.0	3.0	-
	2,4-D	-	14.0	-	-	-	-	11.0	-		-	-	10.0	5.0	3.0	-	10.0
Bannur	SBM	5.0	50.0	18.0	4.0	9.0	-	-	-	-	-	-	18.0	28.0	2.0	12.0	4.0
	PDA	28.0	28.0	-	-	7.0	-	-	-	-	-	-	12.0	11.0	19.0	-	1.0
	WA	62.0	15.0	10.0	8.0	4.0	-	-	-	-	-	-	-	17.0	10.0	-	11.0
	2,4-D	-	18.0	20.0	5.0	-	-	4.0	-	-	-	-	17.0	23.0	42.0	2.0	-
Thubina kere	SBM	22.0	46.0	28.0	10.0	-	-	-	8.0	10.0	-	-	1.0	3.0	4.0	5.0	1.0
	PDA	27.0	21.0	9.0	11.0	-	-	14.0	-	-	-	-	10.0	14.0	11.0	8.0	13.0
	WA	74.0	12.0	-	9.0	4.0	-	8.0	-	-	-	-	23.0	20.0	10.0	25.0	50.0
	2,4-D	-	26.0	10.0	15.0	-	-	-	-	-	-	-	20.0	11.0	4.0	5.0	10.0
Hebbala	SBM	17.0	65.0	22.0	3.0	22.0	10.0	9.0	29.0	-	3.0	-	23.0	16.0	8.0	-	10.0
	PDA	41.0	51.0	-	-	-	-	2.0	-	-	-	-	13.0	3.0	-	18.0	-
	WA	4.0	20.0	-	-	8.0	11.0	10.0	20.0	-	-	-	9.0	4.0	9.0	-	1.0
	2,4-D	-	21.0	-	-	-	10.0	4.0	-		-	-	-	9.0	11.0	10.0	-
Chikka ballapur	SBM	23.0	32.0	11.0	8.0	2.0	-	4.0	4.0	11.0	-	-	2.0	9.0	2.0	4.0	9.0
	PDA	-	10.0	8.0	2.0	1.0	-	-	-	-	-	-	-	14.0	6.0	-	1.0
	WA	2.0	4.0	-	-	-	-	10.0	10.0	-	-	-	1.0	9.0	3.0	5.0	10.0
	2,4-D	-	16.0	11.0	-	-	-	-	-	-	-	-	-	5.0	6.0	4.0	10.0
Mylnalli	SBM	2.0	100	21.0	-	8.0	14.0	-	20.0		20.0	-	31.0	-	-	-	-
	PDA	17.0	68.0	-	-	-	-	-	-		4.0	-	17.0	10.0	6.0	-	14.0
	WA	12.0	11.0	-	-	-	-	-	-		-	-	2.0	-	-	-	-
	2,4-D	-	41.0	-	-	-	-	-	-		-	-	4.0	12.0	10.0	5.0	-

Table 2 Seed mycoflora of castor in different seed health test methods during *kharif*, 2007

Place of collection	Methods	Germ %	Seed mycoflora (%)															
			Fo	Ar	Aa	Cl	Mp	Ch	Cg	Sc	Ss	Ba	Ao	Af	An	Av	Rs
Kalledevarapura	SBM	28.0	32.0	17.0	10.0	-	20.0	11.0	22.0	10.0	-	-	29.0	11.0	3.0	13.0	5.0
	PDA	37.0	33.0	15.0	9.0	3.0	17.0	14.0	-	3.0	5.0	-	23.0	15.0	-	12.0	10.0
	WA	11.0	12.0	10.0	9.0	-	-	-	2.0	-	3.0	-	16.0	15.0	-	15.0	9.0
	2,4-D	-	15.0	11.0	15.0	-	-	6.0	17.0	-	-	-	5.0	4.0	4.0	-	-
Donnehalli	SBM	16.0	16.0	11.0	-	-	4.0	-	25.0	-	-	-	19.0	14.0	-	10.0	-
	PDA	41.0	30.0	6.0	-	-	-	-	25.0	-	-	-	-	25.0	6.0	-	7.0
	WA	18.0	22.0	-	13.0	-	12.0	1.0	-	-	-	-	-	17.0	4.0	6.0	8.0
	2,4-D	-	10.0	-	9.0	-	-	-	9.0	-	-	-	12.0	6.0	-	-	10.0
Arasikere	SBM	25.0	37.0	25.0	11.0	3.0	18.0	10.0	22.0	8.0	-	-	19.0	7.0	5.0	13.0	7.0
	PDA	25.0	28.0	-	4.0	-	12.0	-	24.0	1.0	-	4.0	11.0	11.0	6.0	-	1.0
	WA	33.0	21.0	7.0	11.0	-	18.0	-	32.0	-	-	-	8.0	4.0	-	4.0	5.0
	2,4-D	-	-	1.0	7.0	-	-	-	27.0	-	-	-	6.0	12.0	-	-	9.0
Nelamagala	SBM	35.0	31.0	20.0	-	5.0	18.0	-	32.0	14.0	-	-	15.0	10.0	13.0	20.0	15.0
	PDA	34.0	28.0	19.0	9.0	-	-	-	-	3.0	-	-	11.0	-	10.0	-	10.0
	WA	29.0	12.0	31.0	18.0	-	13.0	-	52.0	-	8.0	-	20.0	41.0	18.0	22.0	13.0
	2,4-D	-	12.0	-	17.0	-	10.0	-	-	-	-	-	10.0	24.0	-	8.0	6.0
Jagalur	SBM	15.0	37.0	5.0	11.0	-	-	-	-	-	-	-	15.0	7.0	5.0	13.0	7.0
	PDA	25.0	28.0	-	-	-	12.0	-	24.0	-	-	-	11.0	11.0	6.0	-	2.0
	WA	33.0	21.0	7.0	11.0	-	7.0	-	25.0	-	-	-	8.0	4.0	-	4.0	5.0
	2,4-D	-	-	-	7.0	-	-	-	27.0	-	-	-	6.0	12.0	-	-	9.0
Vajarahalli	SBM	42.0	27.0	15.0	4.0	-	19.0	-	19.0	16.0	-	-	14.0	10.0	-	-	-
	PDA	34.0	42.0	16.0	-	12.0	-	-	-	6.0	-	-	-	5.0	3.0	6.0	7.0
	WA	37.0	18.0	22.0	16.0	-	12.0	22.0	28.0	-	-	-	11.0	21.0	12.0	-	-
	2,4-D	-	9.0	12.0	13.0	-	3.0	16.0	31.0	-	-	-	-	18.0	7.0	17.0	13.0
Nandhipura	SBM	36.0	58.0	19.0	6.0	-	23.0	-	28.0	15.0	-	6.0	16.0	32.0	-	-	8.0
	PDA	19.0	23.0	15.0	10.0	-	-	12.0	3.0	-	-	-	-	11.0	-	-	8.0
	WA	15.0	18.0	0.0	17.0	-	10.0	-	-	-	-	-	-	-	-	-	9.0
	2,4-D	-	-	8.0	13.0	-	11.0	-	-	-	-	-	-	-	8.0	-	-
Kaidale	SBM	28.0	21.0	5.0	16.0	-	28.0	9.0	8.0	-	-	-	16.0	9.0	7.0	12.0	6.0
	PDA	21.0	19.0	-	9.0	-	-	-	22.0	-	-	-	-	3.0	-	-	6.0
	WA	16.0	21.0	-	8.0	-	9.0	-	-	-	-	-	-	-	11.0	-	-
	2,4-D	-	-	-	-	-	-	-	-	-	-	-	-	8.0	18.0	-	8.0
Birur	SBM	21.0	18.0	9.0	-	2.0	12.0	-	17.0	-	-	-	-	16.0	13.0	-	-
	PDA	23.0	22.0	-	-	-	10.0	-	24.0	-	-	-	-	12.0	20.0	8.0	-
	WA	16.0	21.0	-	8.0	-	9.0	-	-	-	-	-	-	-	11.0	-	-
	2,4-D	-	18.0	-	7.0	-	7.0	-	31.0	-	-	-	-	8.0	-	-	-
Sondekola	SBM	10.0	30.0	-	12.0	-	9.0	7.0	-	-	-	-	-	14.0	-	12.0	-
	PDA	32.0	32.0	11.0	12.0	-	-	-	29.0	-	-	-	-	-	6.0	14.0	14.0
	WA	16.0	21.0	-	8.0	-	9.0	-	-	-	-	-	-	-	11.0	-	-
	2,4-D	-	18.0	-	7.0	-	7.0	-	31.0	-	-	-	-	8.0	-	-	-

Data based on 100 seeds for each sample. Each sample in ten replication

Fo- *Fusarium oxysporum* f.sp. *ricini*
Ar- *Alternaria ricini*
Ao- *Aspergillus ochraceus*
Ss- *Sclerotinia sclerotiorum*
PDA: Potato dextrose agar method

Sc- *Stachysbotrys chartarum*
Aa- *Alternaria alternate*
Af- *Aspergillus flavus*
Ba- *Batryodiplodia acerina*
WA: Water agar method

Rs- *Rhizopus stolonifer*
Cg- *Chaetomium globosum*
An- *Aspergillus niger*
Mp- *Macrophomina phaseolina*
2,4-D: 2,4-D method

Cl- *Curvularia lunata*
Ch- *Cidosporium herbarum*
Av- *Aspergillus versicolor*
SBM: Standard blotter method

Screening of seeds for associated mycoflora: The incubated seeds were observed on eighth day using stereo binocular microscope. The associated mycoflora were recorded in each method and identified with the help of standard guides and manuals.

The analysis of seed-borne mycoflora of castor bean showed occurrence of forty seven species belonging to seven genera. These fungi were isolated from local variety of castor beans. Among the tested samples, the twenty samples shows a higher incidence of fungi. These

samples subjected for potato dextrose agar (PDA), water agar (WA) and 2, 4-Dichloro phenoxy acetic acid (2,4-D) methods and important diseases of corn seed are given in Table 1 and 2.

Seed infection percentage varied from *Fusarium oxysporum* f *sp.ricini* (23-100%), *Alternaria ricini* (2-22%), *Alternaria alternata* (0-10%), *Curvularia lunata* (6-32%) *Macrophomina phaseolina* (10-18%), *Cladosporium herbarum* (2-10%), *Sclerotinia sclerotiorum* (4-20%) *Botryodiplodia acerina* (0-5%), *Stachybotrys chartarum* (6-10%), *Aspergillus ochraceus* (1-31%), *Aspergillus niger* (2-20%), *Aspergillus flavus* (1-28%), *Aspergillus versicolor* (5-12%) and *Rhizopus stolonifer* (1-9%). During *kharif* 2007 the percentage seed infection was more in *Fusarium oxysporum* f.sp. *ricini* (21-58%), *Alternaria ricini* (5-25%), *Alternaria alternata* (4-16%), *Curvularia lunata* (3-5%), *Macrophomina phaseolina* (4-23%), *Cladosporium herbarum* (9-11%), *Chaetomium globosum* (8-28%), *Botryodiplodia acerina* (0-6%), *Stachybotrys chartarum* (3-8%), *Sclerotinia sclerotiorum* (3-8%), *Aspergillus ochraceus* (2-29%), *Aspergillus niger* (3-13%), *Aspergillus flavus* (7-16%), *Aspergillus versicolor* (10-20%) and *Rhizopus stolonifer* (5-15%). These 15 fungi were seen frequently and predominantly in castor beans.

All the seeds associated fungi reduced the germination of castor seeds. The surface sterilized seeds showed a maximum germination percentage. Naik (1994) reported *Fusarium oxysporum* and *Macrophomina phaseolina* significantly reduced germination of castor bean seedlings.

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Short communication

Screening of cold ethyl alcohol extract of *Pongamia pinnata* for insecticidal properties against *Spodoptera litura* Fabricius

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Abstract

Studies revealed that, cold ethyl alcohol leaf extract (25%) of *Pongamia pinnata* followed by topical application was highly effective against *Spodoptera litura* Fab. Growth and development of *S. litura* was drastically affected by the plant extract (20%) followed by leaf application. The adult emergence was normal for both treatments. For topical application, LC_{50} and LC_{90} was found to be 12.28 and 42.53 and for leaf application, 22.50 and 51.21, respectively.

Keywords: Biological insecticide, *Pongamia pinnata, Spodoptera litura*, susceptibility

Chemicals of botanical origin used in pest control management programmes may prevent several adverse effects caused due to synthetic insecticides (Gayatri *et al.*, 2003). Present studies involves application of cold ethyl alcohol extract from the leaves of *Pongamia pinnata* to study its effect on the survival rate of *S. litura* at various stages of development, antifeedant activities and deformities in adults.

Freshly laid batches of eggs of *S. litura* were collected from the castor fields at the University of Agricultural Sciences, Dharwad, Karnataka, India. The eggs were sterilized with 0.05% NaOCl and then with distilled water, transferred to a fresh castor leaf and allowed to hatch under laboratory conditions. The larvae were reared in the laboratory in sterilized earthen pots of 2 l capacity with the mouths of the pots covered securely with a clean sterilized white muslin cloth. The larvae were fed on fresh castor leaves, and maintained at 26±1°C a RH of 65±5% and a photoperiod of L10:D14. The laboratory reared pre-starved fourth instar larvae were used as test insects.0.5, 1, 5, 10, 15, 20, and 25% cold ethyl alcohol extracts of *Pongamia pinnata* leaves were used for the Topical and Leaf application tests.

The shade dried leaves of Pongamia were pulverized in to a fine powder in an electric mixer grinder, and sieved through a muslin cloth. This powder was used for preparing solvent extract within 24 h.500g of the botanical powder was soaked in 500 ml of absolute alcohol (ethyl) and kept overnight. The mixture was stirred with a magnetic stirrer frequently. The solution was then filtered through an ordinary filter paper. The alcohol was allowed to evaporate from the filtrate at room temperature. The plant extract paste was dissolved in 50 ml of acetone. Solutions of 0.5, 1.0,5,10,15,20 and 25% concentrations were prepared from this stock using acetone and used within 24 hours of preparation, for trials.

Under each type of application, the first seven groups were treated with the extract of 0.5, 1.0,5,10,15,20 and 25%. The eighth group was the carrier (acetone control), the ninth, was the absolute control. Each group comprised 20 larvae, kept in 20 separate sterilized earthen pots of 1 liter capacity each and were fed on fresh castor leaves. Extract (2 ml) to be tested was sprayed on the larvae (topical application) and on similar sized castor leaves (and these treated castor leaves were given as food to larvae in leaf application test group.) with a chromatography sprayer. An ordinary cold-air blow dryer was used to hasten the process of drying of the extract on the leaves. Three replications of the test were maintained. Observations were made to assess the total mortality, mortality at the individual stages of development of the insect, feeding deterrence and deformities in the adults. The per cent mortality was corrected using Tukey's honestly significant test. LC_{50} and LC_{90} were calculated using Probit analysis (Finney and David, 1971).

In the topically treated group, feeding was totally stopped by the larvae for the initial 30-45 minutes of application, for 20 and 25% concentrations. Faecal pellets were normal for all the seven treatments. In the leaf application test, this behavior persisted for the initial 65-70 minutes in the 15, 20 and 25% botanical treated subgroups. Feeding, when it was resumed, was slow and intermittent in the next four hours. Pellets were extremely moist and pasty in the 20, and 25% leaf applied larvae. This may be because of loss of peritrophic membrane of the digestive tract in the larvae.

In topical application test and leaf application test, maximum mortality was observed at 25% concentration. This indicated knock-down action of the plant extract. No deformities in adults were observed in the topically treated or the leaf application tests. Deformities and death observed at the larval, pre pupal and pupal stages may be

due to inhibition of chitin synthesis as observed in *S .litura* treated with diflubenzuron, a chitin synthesis inhibitor (Nelson and Venugopal, 2006) .The LC_{50} and LC_{90} were 12.28 and 42.53, respectively. LC_{50} and LC_{90} values for leaf application test were 22.50 and 51.21, respectively. Death in the prepupal stage is ascribed to the slow action of plant products on growth stages of insect or due to the enhanced activity of plant constituents when assimilated in insect tissues. The knock-down effect ,that resulted in mortality in the larvae, may be attributed to the action of the natural product by interfering respiration, leading to asphyxiation, or causing muscle paralysis or affecting the nervous system (Patole *et al.*, 2008).

The present study indicated that both topical and leaf applications of cold alcohol extract of *Pongamia pinnata* leaves are highly effective in controlling *S. litura* at various stages of development.

Table 1 Bioefficacy of cold alcohol leaf extract of *Pongamia pinnata* on development profile of the tobacco cutworm, *Spodoptera litura* Fabricius following topical application on fourth instar larvae

Concentration (%)	Larval (IV, V and VI instar) mortality (%) Mean±SE	Pre-pupal (shrunken stage) mortality (%) Mean±SE	Pupal mortality Mean±SE	Deformed adults Mean±SE	Total mortality (%) Mean ±SE
0.5	18.33±1.66^{e}	5.00±00^{bc}	0^{a}	-	23.33±1.66^{e}
1	25.00±00d^{e}	8.33±1.66^{ab}	1.66±1.66^{a}	-	35.00±00^{de}
5	28.33±1.66^{d}	10.00±2.88^{ab}	1.66±1.66^{a}	-	40.00±2.88^{cd}
10	38.33±1.66^{c}	11.66±1.66^{ab}	1.66±1.66^{a}	-	51.66±1.66^{bc}
15	48.33±1.66^{b}	13.33±1.66^{a}	1.66±1.66^{a}	-	63.33±4.41^{ab}
20	61.66±1.66^{a}	8.33±1.66^{bc}	0^{a}	-	70.00±2.88^{a}
25	70.00±2.88^{a}	3.33±1.66^{ac}	0^{a}	-	73.33±1.66^{a}
Carrier(acetone control)	1.66±1.66^{f}	0^{c}	3.33±1.66^{a}	-	10.00±2.88^{f}
Absolute control	5.00±00^{f}	0^{c}	1.66±1.66^{a}	-	6.66±1.66^{f}
SEm±	1.47	1.19	1.35	-	1.65
"F" test	164.94	7.51	0.80 NS	-	78.44
CD (P=0.05)	4.48	3.63	NS	-	5.01

Means followed by the same letters do not differ significantly from each other at P=0.05 (Tukey's honestly significant test)
LC_{50} = 12.28; LC_{90} = 42.53

Table 2 Bioefficacy of cold alcohol leaf extract of *Pongamia pinnata* on development profile of the tobacco cutworm, *Spodoptera litura* Fabricius following leaf application on fourth instar larvae

Concentration (%)	Larval (IV, V and VI instar) mortality (%) Mean±SE	Pre-pupal (shrunken stage) mortality (%) Mean±SE	Pupal mortality Mean±SE	Deformed adults Mean±SE	Total mortality (%) Mean ±SE
0.5	18.33±1.66^{d}	10.00±00^{ab}	0^{a}	-	28.33±1.66^{d}
1	26.66±1.66^{cd}	10.00±00^{ab}	0^{a}	-	36.66±1.66^{cd}
5	31.66±1.66^{bc}	10.00±2.88^{ab}	1.66±1.66^{a}	-	43.33±1.66^{c}
10	38.33±1.66^{b}	16.66±1.66^{a}	8.33±3.33^{a}	-	58.33±1.66^{b}
15	60.00±2.8^{a}	10.00±2.88^{ab}	0^{a}	-	70.00±00^{a}
20	68.33±1.66^{a}	6.66±1.66^{ab}	0^{a}	-	78.33±1.66^{a}
25	68.33±1.66^{a}	0^{bc}	0^{a}	-	75.00±2.88^{a}
Carrier(acetone control)	5.00±1.66^{e}	0^{c}	1.66±1.66^{a}	-	6.66±1.66^{e}
Absolute control	1.66±1.66^{e}	0^{c}	0^{a}	-	1.66±1.66^{e}
SEm±	1.90	1.85	1.35	-	1.47
"F" test	172.34	5.61	0.89 NS	-	224.75
CD (P=0.05)	5.77	5.61	NS	-	4.48

Means followed by the same letters do not differ significantly from each other at P=0.05 (Tukey's honestly significant test)
LC_{50} = 22.50; LC_{90} = 51.21

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Short communication

Oil quality characteristics and fatty acid composition of castorbean, *Ricinus communis* L. cultivars

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Abstract

Biochemical analysis of 30 castorbean cultivars including 14 varieties, 9 genotypes and 7 hybrids from C.S. Azad University of Agriculture and Technology, Kanpur and Directorate of Oilseeds Research, Hyderabad, India revealed sizable variability in oil quality characteristics.

Keywords: Castorbean, oil quality, fatty acids, ricinoleic acid

Castor (*Ricinus communis* L.) is one of the ancient oilseed crops of the world with diversified uses (Hegde *et al.*, 2003). Castor oil is industrial grade oil containing high content of single fatty acid and ricinoleic acid. The oil content of the castor seeds have been found to vary due mainly to differences in genetic makeup of the varieties. Variability in oil content and fatty acid profile of seeds of castor varieties indicated a great potential of selecting high oil containing varieties for industrial use (Ramos *et al.*, 1984; Lakshminarayana *et al.*, 1984). To explore the potential of these genotypes or hybrids, the present work was undertaken to select varieties/genotypes/hybrids having high oil content and better oil quality characteristics.

Thirty promising cultivars of castor were obtained from Oilseeds Section, C.S. Azad University of Agriculture and Technology, Kanpur and DOR, Hyderabad. Oil content was estimated by Soxhlet method using n-hexane (AOAC, 1974). Oil quality was determined as per methods. Acid value (Cox and Pearson, 1962), saponification value and hydroxyl value by AOAC (1970), iodine value by Jamieson (1943). Oil samples extracted from seeds of different castor genotypes using n-hexane as solvent were converted to methyl esters. Methyl esters of different fatty acids were separated on Gas Chromatograph, Varian Gas Chromatography, model 3900 with data handling workstation and a data processor. Gas Chromatography was carried out using silica packed WCOT capillary column No. CP 7485 following standard procedures. Standard methyl esters were used as reference to characterized different fatty acids. Percentage of fatty acid was based on peak area and retention time recorded by automatic computerized GC data processor.

Oil content in different castor genotypes significantly varied from 45.9 to 56.4% (Table 1). Amplitude of variability was maximum (10.5%) in varieties. Moreover, differences between 3 groups were found to be significant. Aruna followed by Bhagya and Chandraprabha were identified as high oil containing varieties while Prabha-9801, KC-123 and KC-63 topped the list of genotypes in having higher levels of oil content whereas in hybrids RHC-1, GCH-5 and DCH-32 were identified to be rich in oil. Similar findings on the variability of oil content have also been reported (Nagaraj, 1990).Saponification and iodine values showed very large and significant variations (Table 1). Our results are in agreement with the findings of Patel *et al.* (2004).

The fatty acids profile of the castor seed oil as revealed by Gas Chromatography which can be grouped under three distinct types depending on their peak area and mean fatty acid levels. Palmitic acid, stearic acid, dihydroxy stearic acid, arachidic acid, linolenic acid and arachidonic acid formed a group of minor fatty acids of castor oil, the mean values of which figured below the level of 3% (Table 2). Castor oil possessed little higher concentration of oleic and linoleic acid. The seed oil samples contained the largest concentration of ricinoleic acid (Table 2). Content of oleic and linoleic acid also showed significant variations. Other fatty acids *viz.*, palmitic, stearic, linolenic, arachidic, arachidonic and dihydroxy stearic acids appeared in small concentrations and showed small range of variation (Table 2). Our results in respect of fatty acid composition of different castor cultivar are in agreement with Ramos *et al.* (1984) and Lakshminarayana *et al.* (1984).

Based on the findings generated during the present investigation, it may be concluded that commercially, hybrids are most economically viable for the production of significantly superior oil yield and industrially valuable ricinoleic acid as compared to varieties and genotypes.

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Table 1 Variability in oil characteristics of different castorbean cultivars

Entries	Oil content (%)	AV	SV	IV	HV
Varieties					
Balliachayan	53.8	2.57	184.83	87.50	164.3
Bhagya	54.9	2.12	187.00	87.04	165.1
Chandraprabha	54.4	2.67	184.77	86.91	163.8
Aruna	56.4	2.24	186.25	87.63	164.2
Kalpi-6	52.0	2.77	183.40	86.85	163.1
Tarai-4	54.1	2.74	177.38	87.47	162.5
Type-3	51.4	2.88	181.25	83.19	161.7
SKI-272	46.2	2.85	179.27	89.29	162.6
SKI-281	47.9	2.90	175.84	88.88	163.1
SKI-295	47.1	2.81	178.69	88.08	161.7
SKI-299	45.9	3.25	179.86	89.56	162.4
Kranti	50.8	2.94	176.84	88.92	163.8
DCS-9	49.8	2.86	176.61	87.31	160.8
48-1 (Jwala)	49.2	2.65	183.32	88.14	163.4
Mean	51.0	2.73	181.10	87.63	163.0
SEm ±	0.3	0.10	0.46	0.56	0.44
CD (P=0.05)	0.6	0.19	0.92	1.13	0.90
Genotypes					
Prabha-9801	53.5	2.74	179.09	91.77	163.2
KC-1	50.9	2.78	177.72	88.26	160.2
KC-19	51.5	2.89	179.27	89.29	160.9
KC-39	50.9	3.18	181.38	89.80	161.3
KC-40	52.2	2.66	179.86	89.87	160.7
KC-48	52.8	2.72	176.84	87.07	162.5
KC-56	52.6	2.82	179.86	87.87	161.8
KC-63	52.9	2.63	181.38	88.45	160.5
KC-123	53.1	2.83	176.61	86.62	162.0
Mean	52.2	2.80	179.11	88.78	161.4
SEm±	0.3	0.10	0.46	0.56	0.44
CD (P=0.05)	0.6	0.19	0.92	1.13	0.90
Hybrids					
GCH-4	49.3	2.88	182.22	87.42	160.0
GCH-5	50.2	3.01	179.70	88.37	159.7
GCH-6	49.1	2.65	176.31	90.34	161.5
RHC-1	50.6	3.13	182.75	86.42	162.6
DCH-32	59.5	2.80	180.32	86.50	163.2
DCH-177	48.0	3.00	184.83	87.50	161.4
DCH-519	48.8	2.91	179.86	87.97	162.3
Mean	49.3	2.91	180.85	87.79	160.8
SEm±	0.1	0.10	0.46	0.56	0.4
CD (P=0.05)	0.6	0.19	0.92	1.13	0.9
SEm± between (VxG)	0.1	0.03	0.14	0.17	0.1
CD (P=0.05) between (VxG)	0.2	0.06	0.28	0.34	0.3
SEm± between (VxH)	0.1	0.03	0.15	0.18	0.1
CD (P=0.05) between (VxH)	0.2	0.06	0.30	NS	0.3
SEm± between (GxH)	0.1	0.03	0.16	0.20	0.2
CD (P=0.05) between (GxH)	0.2	0.07	0.33	0.40	0.3

AV = Acid value; SV = Saponification value; IV = Iodine value; HV = Hydroxyl value

Table 2 Fatty acid composition of different cultivars of castorbean oil

Entries		Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Arachidic acid	Arachidonic acid	Ricinoleic acid	Dihydroxy stearic acid
Varieties										
Balliachayan		2.33	2.89	9.31	9.82	0.93	0.89	-	73.83	-
Bhagya		2.20	2.62	7.68	8.78	0.96	0.66	-	77.10	-
Chandraprabha		1.89	1.94	6.31	8.40	0.73	0.79	-	79.94	-
Aruna		2.52	2.73	9.95	9.90	0.99	0.92	-	72.94	0.05
Kalpi-6		1.95	2.44	8.70	9.07	0.75	1.19	-	75.85	0.05
Tarai-4		2.33	2.90	11.70	9.82	0.96	1.05	-	71.16	0.08
Type-3		1.89	2.53	9.71	9.07	1.16	6.69	-	68.96	-
SKI-272		3.05	3.19	10.12	12.33	1.32	1.29	-	68.58	0.12
SKI-281		3.00	3.22	8.47	11.92	1.15	0.92	-	71.23	0.09
SKI-295		2.67	2.60	7.19	10.38	0.99	0.66	-	75.40	0.11
SKI-299		3.36	3.42	8.13	13.01	1.21	0.95	-	69.92	-
Kranti		2.40	2.59	7.42	10.96	0.98	0.67	-	74.98	-
DCS-9		2.53	2.66	6.79	9.69	0.79	0.46	-	76.99	0.09
48-1 (Jwala)		2.77	2.92	8.73	10.89	0.86	0.56	-	73.18	0.09
	Mean	2.49	2.76	8.59	10.29	0.98	1.26	-	73.58	0.08
	SEm ±	0.23	0.30	0.37	0.41	0.17	0.24	-	0.31	0.01
	CD (P=0.05)	0.46	0.59	0.74	0.83	0.34	0.48	-	0.62	0.03
Genotypes										
Prabha-9801		3.27	3.33	11.61	15.18	1.47	1.64	-	63.50	-
KC-1		2.56	3.07	9.90	10.90	1.03	1.02	-	71.52	-
KC-19		3.18	3.04	10.29	13.07	1.11	1.81	-	67.50	-
KC-39		3.00	2.96	10.79	12.95	1.20	1.27	0.28	67.56	-
KC-40		2.42	2.17	8.70	11.29	1.57	0.97	0.69	72.20	-
KC-48		1.42	1.32	5.85	7.68	0.67	0.71	-	82.35	-
KC-56		2.43	2.82	8.23	10.57	0.79	0.85	-	74.28	0.03
KC-63		2.51	2.64	8.73	11.21	0.99	0.89	0.54	72.46	0.03
KC-123		2.06	2.71	9.49	8.62	0.96	1.13	-	75.01	0.02
	Mean	2.54	2.67	9.29	11.27	1.09	1.14	0.50	71.82	0.03
	SEm±	0.23	0.30	0.37	0.41	0.17	0.24	0.22	0.31	0.01
	CD (P=0.05)	0.46	0.59	0.74	0.83	0.34	0.48	NS	0.62	NS
Hybrids										
GCH-4		2.02	2.42	7.07	9.11	0.85	0.52	-	77.87	0.14
GCH-5		2.50	3.05	10.76	11.23	0.96	1.14	-	70.27	0.09
GCH-6		3.25	3.85	13.31	13.72	1.50	1.33	-	62.96	0.09
RHC-1		1.99	2.06	5.92	8.19	0.65	0.58	-	80.45	0.17
DCH-32		1.67	1.84	7.00	7.78	0.65	0.68	-	80.28	0.10
DCH-177		2.25	2.39	8.15	9.59	0.79	0.76	-	75.99	0.09
DCH-519		2.28	2.68	8.24	10.25	0.86	0.75	-	74.85	0.09
	Mean	2.28	2.61	8.63	9.98	0.89	0.82	-	74.67	0.11
	SEm±	0.23	0.30	0.37	0.41	0.17	0.24	-	0.31	0.01
	CD (P=0.05)	0.46	0.59	0.74	0.83	0.34	0.48	-	0.62	0.03
SEm± between (VxG)		0.07	0.09	0.11	0.12	0.05	0.07	-	0.09	0.007
CD (P=0.05) between (VxG)		NS	NS	0.22	0.25	0.10	NS	-	0.19	0.015
SEm± between (VxH)		0.07	0.10	0.12	0.13	0.05	0.08	-	0.10	0.006
CD (P=0.05) between (VxH)		0.15	NS	NS	0.27	NS	0.15	-	0.20	0.011
SEm± between (GxH)		0.08	0.10	0.13	0.15	0.06	0.08	-	0.11	0.007
CD (P=0.05) between (GxH)		0.16	NS	0.26	0.29	0.12	0.17	-	0.22	0.015

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Short communication

Development of a bullock drawn groundnut, *Arachis hypogaea* L. digger suitable for coastal Orissa

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Abstract

A ridger type bullock drawn groundnut digger was developed and tested for power requirement, effective field capacity, field efficiency, labour requirement, pod losses, digging of coastal Orissa. The average draft requirement and power requirement of the digger were observed to be 57.0 kgf of 0.39 h.p., respectively which are within the capacity of an average pair of bullock. The maximum digging efficiency of 91.8% was found under an optimum speed of 1.9 km/hr. The performance index was observed as 0.101 considering the quality and quantity of digging along with power requirement for its operation. The performance of this bullock drawn groundnut digger was satisfactory and economical. The use of the digger is within the reach of small and marginal farmers growing groundnut crop on a commercial basis.

Keywords: Groundnut, digger, power requirement, field efficiency, pod losses, digging efficiency

Groundnut (*Arachi hypogaea* L.) is the major oilseed crop of India. Orissa produces 3.78 lakh tonnes of groundnut per year with a production rate of 15.99 q/ha. Major cultivation of groundnut is in the districts of Cuttack, Khurda, Dhenkanal, Jaipur, Ganjam, Sambalpur and Kalahandi (Anonymous, 2008). The socio-economic conditions of farmers of Orissa do not permit them to use tractor, power tillers and their matching implements. Keeping these problems in view, a ridger type bullock drawn groundnut digger was developed and tested at farmers' field in April, 2004.

A ridger shaped digging blade for groundnut having internal angle of 50° was fabricated from 3 mm thick mild steel sheet (Fig. 1). On the blade there was a mild steel plate frame over which the handle was fixed. A beam made of wood of size 245 x 6 x 4 cm was attached to the frame. The required numbers of holes were made for adjustments.

The equipment was tested in the farmers' field at village Debil of Khurda district, Orissa for digging of AK-12-24 variety groundnut as per standard test procedures (I.S.: 11235-1985). Observations on power requirement, effective field capacity, field efficiency, labour requirement pod losses, digging efficiency, performance index and economics of digging were recorded. The moisture content of pod, vine and soil were determined by air over method by dry weight basis. The draft, power requirement and effective field capacity were measured during the test. The pods left on the surface, within the soil and damaged pods were collected separately from the specified area to determine the losses.

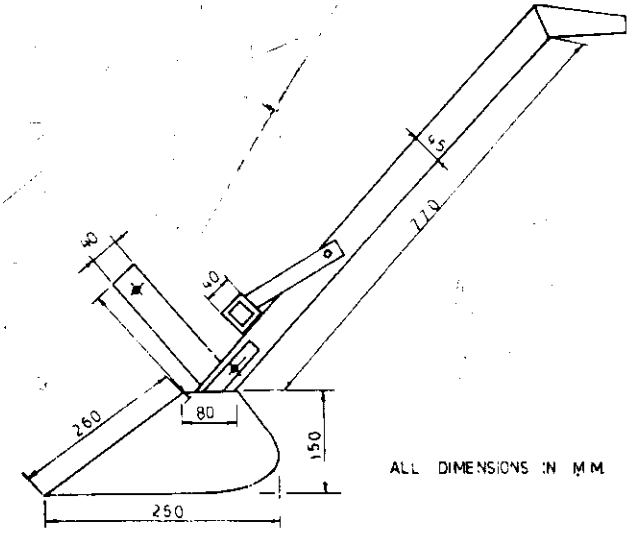

Fig. 1. Groundnut digger (Ridger type)

Percentage of exposed pod loss, L_a = G/A x 100

Percentage of unexposed pod loss, L_b = H/A x 100

Percentage of undug pod loss, L_c = K/A x 100

Where,

G = quantity of detached pods lying exposed on the surface;
H = quantity of detached pods remained inside the soil in the sample area;
K = quantity of pods remained undetached from the undug plants in the sample area
A = total quantity of pods collected from the plants in the sample area.

Total percentage of pod loss = percentage of (exposed + unexposed + undug) pod loss

Digging efficiency = 100 - total percentage of pod loss

Draft, D = P Cos Ø

Where,

D = draft in kgf; P = pull in kgf; Ø = angle between line of pull and horizontal plane

Power requirement, H.P. = (Draft in kgf x speed in m/sec)/75

Effective field capacity: It is the actual rate of coverage. It includes the time lost making adjustment, unclogging the blades, etc. It is expressed in hectares per hour.

Field efficiency: It is the ratio of effective field capacity to theoretical field capacity and is expressed in percentage.

Labour requirement: It is the number of labours required for one ha area for digging groundnut.

$$\text{Performance index} = \frac{(1-L_a)\,(1-L_b)\,(1-L_c) \times W_d \times b_D \times 75}{R_L \times D_D}$$

Where, W_d = total weight of groundnut dug in kg
b_D = width of cut of groundnut digger in meter
R_L = length of run in meter
D_D = draft of groundnut digger in kgf

The draft required to run the groundnut digger varied from 50.2 to 63.9 kgf with an average value of 57.0 kgf and the power requirement from 0.31 to 0.48 hp with an average value of 0.39 hp (Table 1). The average theoretical and effective field capacities were found to be 0.065 ha/hr and 0.058 ha/hr, respectively. The draft and effective field capacity of a riding type bullock drawn groundnut digger developed at TNAU, Coimbatore were reported as 100 kg and 0.09 ha/hr, respectively (Devnani, 1978). The results obtained from the performance evaluation of the above digger corroborated with the results of developed ridger type groundnut digger. The draft and field capacity of the ridger type groundnut digger was also found to be of some range as obtained by Quadri (1988) from the field evaluation of a semicircular blade groundnut digger in Maharashtra.

The effect of speed on effective field capacity of the groundnut digger is shown in Fig. 2. The average field efficiency was found to be 89%. The optimum operating speed to achieve maximum digging efficiency was 1.9 km/hr with a digging efficiency of 91.8%. The average digging efficiency was found to be 90.1%. The variation of digging efficiency with respect to speed of operation of the digger is shown in Fig. 3. The performance index of the groundnut digger was found to be 0.101 considering the quality of digging, quantity of digging and power requirement for the operation. The cost of operation in case of manual digging method was found to be Rs.1100/ha as compared to Rs. 653.40/ha in this ridger digger, but the effective field capacity of the said digger (0.058 ha/hr) is much higher than manual method (0.0075 ha/hr). The performance of the developed groundnut digger was satisfactory and found to be suitable for harvesting of groundnut in sandy loam soil of coastal Orissa.

Table 1 Average values of power requirement, losses, field efficiency, digging efficiency, performance index and cost of operation of two row riding type groundnut digger

Speed (km/hr)	1.86
Draft (kgf)	57.0
H.P.	0.39
Effective field capacity (ha/hr)	0.058
Theoretical field capacity (ha/hr)	0.065
Field efficiency (%)	89.23
Labour requirement (man hr/ha)	52.18
Exposed pod loss (%)	3.6
Unexposed pod loss (%)	5.5
Undug loss (%)	0.8
Total loss (%)	9.9
Digging efficiency (%)	90.1
Width of cut (cm)	35.0
Performance index	0.101
Cost of operation (Rs/ha)	653.40

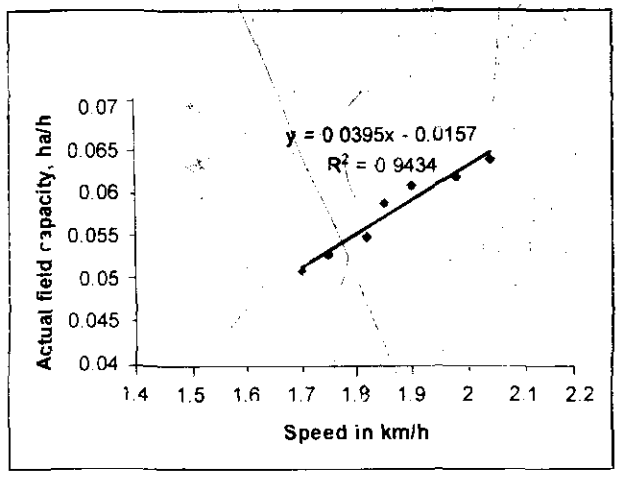

Fig. 2. Effect of speed on actual field capacity

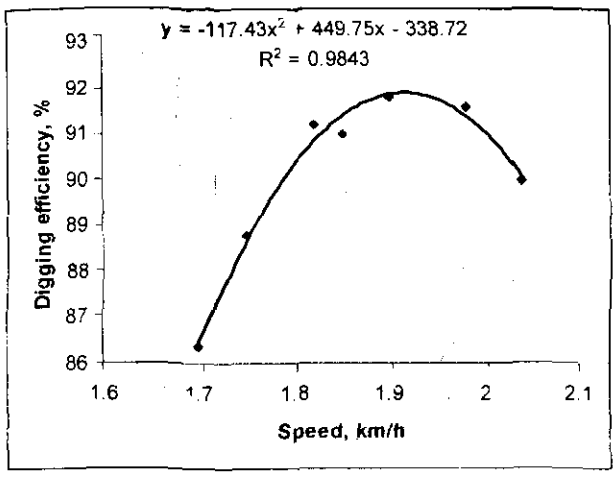

Fig. 3. Effect of speed on digging efficiency

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