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Genetic divergence analysis in some bold seeded genotypes of groundnut, *Arachis hypogaea* L.

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Abstract

A field experiment was conducted with 48 newly developed groundnut genotypes to study the diversity among the genotypes, which were grouped into 13 clusters revealing the presence of considerable amount of genetic diversity in the material. Cluster I had the maximum number of 19 genotypes followed by cluster II with 10 genotypes and cluster IV with 6 genotypes. The intra cluster distance ranged from 0.00 to 12.34. The highest intra cluster distance was observed for cluster IV (12.34) followed by cluster I and II. The inter cluster D^2 values ranged from 11.48 to 89.42, the maximum inter cluster distance was observed between the clusters VII and XII (89.42) followed by II and XII (78.81) and VI and VII (77.93), which indicated that the genotypes included in these clusters will give high heterotic response and thus better segregants. Among the 12 characters studied 100 seed weight contributed the most (75%) towards the divergence of genotypes.

Key words: Groundnut, genetic divergence, genetic distance and hybridization

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the chief protein rich vegetable oilseed crops of India. Hand picked selection (HPS) or large seeded groundnut also referred as confectionary groundnut gaining much more importance in recent years in view of its export potential. Groundnut is a highly self pollinated crop as a result the variability observed within the habit groups reported to be very low (Emery and Wynne, 1976). Genetic variability and divergence are of greater interest to the plant breeder as they play a vital role in framing a successful breeding programme. The nature and magnitude of genetic divergence in a population is essential for selection of diverse parents, which upon hybridization leads to a wide spectrum of gene recombination for quantitatively inherited traits. Crosses between divergent parents usually produce greater heterosis than those between closely related ones (Moll and Stuber, 1971). Among the several multivariate analyses, the Mahalanobis D^2 (1936) technique is a unique tool for identifying the degree of genetic divergence in a biological population. The objective of this research was to study the magnitude of genetic divergence, and the characters contributing to it among 48 large seeded groundnut genotypes using the D^2 statistic.

Material and methods

The material for the present study comprised of 48 newly developed, bold seeded groundnut genotypes (includes 33 bunch and 15 semi-spreading genotypes) The experiment was conducted at the Department of Oilseeds, CPBG, TNAU, Coimbatore, during *rabi*, 2002-03. Each genotype was sown in 2 rows of 4 m length spaced at 45 cm with inter-plant distance of 10 cm. The experiment was laid out in a Randomized Block Design with three replications. In each entry five plants were randomly tagged and utilized to collect data on pod yield and pod associated characters (Table 2). The data were subjected to statistical analysis using Mahalanobis D^2 statistics (Mahalanobis, 1936) and Tocher's method as described by Rao (1952) for determining the group constellation. Average intra and inter clusters distances were estimated as per Singh and Chaudhary (1977).

Results and discussion

The analysis of variance revealed significant differences among the genotypes for all the traits studied. Based on D^2 statistics, the 48 genotypes were grouped into 13 clusters with variable numbers of genotypes revealing the presence of considerable amount of genetic diversity in the material. Cluster I had the maximum number of genotypes (19) followed by cluster II with 10 genotypes and cluster IV with six genotypes. The two clusters I and II together included 29 genotypes reflecting a narrow genetic diversity among them. Further, clusters V and VI had two and three genotypes, respectively. While the rest of the clusters III, VII, VIII, IX, X, XI, XII and XIII were solitary clusters demonstrating the impact of selection pressure in increasing the genetic diversity.

The intra cluster distance ranged from 0.00 to 12.34 with highest intra cluster distance for cluster IV (12.34) followed by I and II. Such intra cluster genetic diversity among the genotypes could be due to heterogeneity, genetic architecture of the populations, past history of selection in developmental traits and degree of general combining

ability (Dikshit and Swain, 2000; Mahapatra *et al.*, 1993). The cluster V showed minimum intra cluster value of 6.48 indicating that the genotypes within this cluster were similar (Table 1).

The inter cluster D^2 values ranged from 11.48 to 89.42, the maximum inter cluster distance was observed between the clusters VII and XII (89.42) followed by II and XII (78.81) and VI and VII (77.93) which indicated that the crosses among the genotypes included in these clusters may give high heterotic response and thus better segregants. The minimum inter cluster distance was observed between cluster III and IV (11.48) indicating the close relationship among the genotypes in these clusters.

The cluster mean of each trait towards divergence are presented in Table 2 respectively. The data revealed that considerable differences existed among the clusters for most of the characters studied. The cluster V (CO 3 and TNAU 9625-2) recorded the highest mean values for six characters *viz.*, number of mature pods, pod weight, total number of kernels, kernel weight, sound mature kernel number and sound mature kernel weight. The cluster XII (ICGV 96110) showed the highest mean values for number of secondary branches and 100 seed weight.

The data on inter-cluster distances and *per se* performance of genotypes were used to select genetically diverse and agronomically superior genotypes. On this basis of the maximum inter cluster values and *per se* performance for yield/plant and 100-seed weight, the genotypes CO 2, TNAU 9712-10, ICGV 96110, TNAU 9516 and ICGV 94222 were selected. The characters contributing to most of the divergence should be given more importance for the purpose of effective selection and the choice of parents for hybridization. Among the 12 characters studied 100-seed weight contributed the most (75%) towards the divergence of genotypes followed by number of mature pods, kernel weight and oil content, where as all the other characters contributed the least divergence indicating narrow diversity for those characters among the genotypes under study.

Table 1 Intra (diagonal) and inter cluster distances among 13 clusters in groundnut

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I	**11.20**	19.65	14.49	20.12	31.18	51.15	28.87	20.39	15.62	19.55	48.77	62.84	33.31
II		**11.80**	27.96	34.58	43.67	67.39	14.92	33.78	18.84	16.08	64.34	78.81	49.20
III			**0.000**	11.48	18.81	42.27	37.65	19.77	19.72	23.31	37.36	52.94	24.09
IV				**12.34**	21.10	35.82	44.60	17.16	25.28	31.48	32.63	46.55	18.54
V					**6.48**	37.83	52.51	33.60	34.83	37.07	28.15	46.09	24.02
VI						**9.85**	77.93	38.12	55.77	64.62	16.27	14.66	20.19
VII							**0.000**	43.37	25.87	20.38	74.68	89.42	59.90
VIII								**0.000**	23.56	35.74	40.56	50.28	22.98
IX									**0.000**	22.41	54.06	67.56	39.16
X										**0.000**	58.81	74.79	46.46
XI											**0.000**	18.91	19.11
XII												***0.000***	*31.03*
XIII													**0.000**

Table 2 Character means in different clusters of groundnut genotypes

Cluster	Plant height *(cm)*	No. of Primary *branches*	No. of secondary *branches*	Number of mature *pods*	Pod weight (g)	Total number of kernels	Yield/plant (g)	Sound mature kernel no.	Sound mature kernel weight (g)	Shelling %	100 seed weight (g)	Oil content (%)
I	20.95	3.99	3.23	20.25	18.30	35.81	11.10	31.56	9.75	60.88	35.19	45.47
II	19.24	4.00	3.45	18.85	14.83	34.37	9.06	28.39	7.79	61.72	29.20	46.09
III	23.40	4.00	2.50	18.30	21.30	33.60	13.15	29.85	11.40	61.65	37.15	46.15
IV	22.15	4.00	3.43	19.40	21.17	33.76	12.50	28.53	10.59	59.44	40.43	45.73
V	19.00	4.00	2.83	22.05	*29.95*	*36.55*	*19.63*	*31.70*	17.03	*65.78*	*38.68*	46.70
VI	24.38	4.00	3.97	20.17	23.87	34.80	14.87	30.47	12.75	61.78	53.42	45.76
VII	22.55	4.00	4.30	19.60	15.45	29.90	6.40	26.55	6.40	41.90	24.65	46.85
VIII	22.45	4.00	1.90	18.40	46.30	14.35	30.30	7.65	28.50	67.25	53.50	42.65
IX	18.65	4.25	3.40	18.10	15.40	32.35	10.10	27.20	7.55	65.60	34.05	49.95
X	19.50	4.00	3.00	17.90	21.25	36.20	11.05	31.20	9.05	51.95	28.35	*45.10*
XI	20.90	4.00	5.00	17.60	27.25	33.30	16.90	30.85	15.20	62.00	49.10	44.80
XII	23.55	4.00	5.30	17.60	26.00	31.05	14.40	26.90	12.75	55.40	56.60	45.10
XIII	23.20	4.00	5.20	19.70	21.30	34.05	14.35	31.00	12.40	67.60	46.85	44.05

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Analysis of correlations and path effects among yield attributing traits in two crosses of large seeded groundnut, *Arachis hypogaea* L.

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Abstract

Investigations to know the nature and magnitude of associations among 10 quantitative traits and their contribution towards pod yield was carried out in two segregating populations of large seeded groundnut TKG 19 A x J 11 and J 11 x TGLPS 3. The results revealed that total number of pods, number of well filled pods, 100 kernel weight, SMK percent and days to flowering had positive and significant association with pod yield in both the crosses. However, the association of shelling percent was significant only in the cross J 11 x TGLPS 3. The negative relationship of pod yield with damage due to *S. litura* and late leaf spot (LLS) indicate that their incidence reduce pod yield severely. Among the yield components, 100-kernel weight exhibited positive association with shelling and SMK percent indicating that it is possible to develop genotypes having large kernels coupled with better shelling and uniform kernels. Path analysis revealed that number of well-filled pods has been an important trait to influence pod yield directly in the cross TKG 19 A x J 11, whereas total number of pods and kernel weight in the cross J 11 x TGLPS 3. The well filled pods also contributed indirectly towards pod yield through total number of pods, shelling percent and SMK %. The biotic stresses due to incidence of *S.litura* and LLS showed significant negative direct effects towards pod yield so also indirectly through component traits.

Key words: Large seeded groundnut, association, *path analysis*

Introduction

The cultivation of large seeded groundnut (*Arachis hypogaea* L.) in India assume importance in recent years in view of its export potential to earn the foreign exchange. Unlike the commercial cultivars for oil extraction, the large seeded types meant for export need to satisfy several quality standards. The desirable cultivar should possess kernels weighing more than 70 g after grading. With the increase in pod size their shelling percent is affected and needs to be improved when compared to commercial oil types (above 70 %). The large kernels is also associated with uneven kernels, which affect the market value. The genotypic differences do exist among large seeded cultivars for SMK %, 100 seed weight and proportion of large kernels offering scope for improvement. Though, all these seed traits are highly influenced by the environment, the role of GxE interactions can be minimized to maintain specific seed standards by agronomic manipulations and choosing appropriate growing seasons. The large seeded cultivars also suffer due to occurrence of foliar and soil borne fungal diseases, affecting the quality of the produce. Groundnut meant for export has to satisfy a number of other confectionery characteristics such as physical, biochemical and sensory with the least invasion by *A.flavus* (Dwivedi and Nigam, 1995). Keeping the above aspects in mind, efforts were made to establish interrelationships among various yield traits and also their contribution towards pod yield in the segregating populations of two large seeded genotypes. This will facilitate the breeder to design appropriate selection strategies to combine higher pod yield with better confectionery characteristics in a large seeded genotype.

Material and methods

Experimental material for the present study consisted of parents, F_1, F_2 and back cross populations of two crosses viz., TKG 19 A x J 11 and J 11 x TGLPS 3 chosen from six generation mean analysis. The parent J 11, a Spanish bunch variety with normal size kernels (30-35 g/100 kernels) known to possess higher levels of resistance to aflatoxin build up was crossed with two Virginia bunch genotypes TKG 19 A and TGLPS 3 with large seeds during *kharif* 2002. The genotypes found susceptible to *A .flavus* fungal invasion and need incorporation of resistance. The F_1's were grown during summer 2003 to obtain back crosses and their F_2 generations.

The F_2 populations of both the crosses were sown with their parents and back crosses in a Randomized Block Design with three replications at the Main Agricultural Research Station, Dharwad during *kharif* 2003. The plot size consisted of three rows of 5.0 m length for parents, F_1's and back crosses, while 12 rows for the F_2's. A spacing of 30 cm and 10 cm was given between and within rows, respectively. Hand dibbling was done to maintain proper spacing and optimum plant stand. All other agronomic practices were followed to raise a successful experimental crop.

Observations were recorded on 100 plants at random in each replication of the segregating populations and 10 plants per replication in parental lines for 8 quantitative characters *viz.*, days to 50% flowering, number of filled pods, number of unfilled pods, total number of pods, pod yield, shelling percent, sound mature kernels, 100-kernel weight. The observations on *Spodoptera litura* and late leaf spot damage were recorded by following 1-5 and 1-9 scale, respectively and converted to percent incidence. The genotypic correlations were worked out by using the formula as suggested by Johnson *et al.* (1955) and path analysis in accordance with Dewey and Lu (1959).

Results and discussion

The nature and magnitude of genotypic correlation coefficients (Table 1) obtained among ten characters in two F_2 populations of TKG 19 A x J 11 and J 11 x TGLPS-3 revealed that total number of pods exhibited a strong association with pod yield in both the crosses (0.820 and 0.583), indicating that genotypes possessing higher number of pods always result in higher pod yield. The earlier studies also indicate the importance of total number of pods and as one of the important yield components (Rosemary and Ramalingam, 1997; Sarala and Gowda, 1998). Since total number of pods is the product of both well filled and unfilled pods, the association of well filled pods with the pod yield is more important rather than the total number of pods. In the present studies, number of well filled pods had significant association with pod yield in both the crosses (0.785 and 0.683), while number of unfilled pods associated weakly with the pod yield indicating that positive association of total number of pods has come from association of well filled pods with the pod yield (Pushkaran and Nair, 1993; Sumathi and Ramanathan, 1995; Rosemary and Ramalingam, 1997; Sarala and Gowda, 1998). The character 100-kernel weight an index of kernel size exhibited positive and significant association with pod yield (0.224 and 0.568), indicating that any increase in kernel size is responsible for higher pod yield, which is in accordance with the earlier studies made by Sumathi and Ramanathan, (1995); Sarala and Gowda, (1998). The shelling percent had positive but non significant association with pod yield in both the crosses (0.060 and 0.211). But many of the earlier studies indicate its strong association with pod yield (Reddy and Gupta, 1992, Sharma and Varsheney, 1995), which perhaps due to involving high shelling commercial oil types in the studies. Thus, it is very essential to improve the shelling of large seeded types to realize higher kernel yield. The cross J11 x TGLPS 3 can be considered as the best for effecting selections for improved shelling, in view of considerable strength of positive association (0.211). The pod yield is also found to have significant and positive association with SMK percent (0.230 and 0.396), which is in conformity with the findings of Reddy and Gupta (1992). Considering the association of pod features with pod yield, it is desirable to have genotypes with more number of well filled pods with better shelling, 100 kernel weight and higher proportion of uniform large kernels to attract both consumers and also the producers. Days to 50 % flowering had positive and significant association with number of pods and number of mature pods. Thus, selection of genotypes having longer duration is essential in order to have higher number of pods per plant. These findings are in conformity with the results of Shetter (1974). A positive association of number of mature pods per plant with shelling (Swamy Rao *et al.*, 1988) and SMK per cent (Lin *et al.*, 1969) support the view that any selection directed towards achieving higher number of pods is always associated with good shelling as well as SMK %. On the contrary, these two traits observed to have negative association with immature pods indicating that there is a need to develop genotypes which can put forth flowers, effective peg initiation and pod development almost in a narrow span of time, so that immature pod formation could be minimized. This is quite essential in large seeded types where the differences in pod maturity is considerably large thus leading to higher proportion of uneven pods and in turn kernels. The genotypes having uniform kernels normally fetch premium value, and a better relationship do exists between kernel weight and SMK percent (Ramanathan and Raman, 1968) indicating that it is possible to develop genotypes having larger kernels with higher proportion of uniform kernels. The associations of biotic stresses like incidence of late leaf spot (LLS) and *Spodoptera litura* were significant but negative with pod yield, number of pods, kernel weight and shelling percent in both the crosses indicating that incidence of biotic stresses will not only reduce pod yield but also affect quality of pods (Gowda *et al.*, 1996 and Motagi *et al.*, 1997). Therefore, the study clearly indicates that incorporation of resistance to biotic stresses in large seed types is essential to minimize chemical spray and accumulation of pesticidal residues.

The direct and indirect path effects (Tables 2) revealed that the characters number of well filled pods had the greatest direct effects (0.4674) towards pod yield followed by SMK % (0.0707) and 100 kernel weight (0.0542) in TKG 19 A x J 11, confirming the positive association. However, total number of pods had the major direct effect (0.1217) towards pod yield in the cross J 11 x TGLPS 3 followed by 100 kernel weight (0.1006) and SMK % (0.0542). Thus, the studies clearly reveal that total number of pods but well filled with larger kernels and SMK % are the major determinants of pod yield in large seeded groundnut. The above results are in conformity with the findings of Deshmukh *et al.* (1987) for number of filled pods and 100-kernel weight and Abraham, (1990) for shelling percent. It is also interesting to note that though the direct effects of total number of pods and SMK %

towards pod yield was negative or low in the cross TKG 19A x J 11, they influenced indirectly through number of filled pods (0.4462 and 0.1486, respectively) supporting positive association with pod yield. The direct contribution of days to flowering towards pod yield appeared to be low, but at the same time its indirect influence through other traits has been considerable. The incidence of LLS and *S.litura* had negative influence on pod yield both directly and also indirectly through the components traits, indicating the need for their control or to have in built resistance for these biotic stresses.

Based on the studies of associations and path effects, it can be opined that the traits total number of pods, number of well filled pods, 100 kernel weight and SMK per cent can be considered as important for obtaining higher pod yield and therefore, selection may be initiated for improvement of these component traits to achieve higher pod yield.

Table 1 Genotypic correlation coefficients among component characters in two F_2 populations of groundnut

Character	F_2 Population	No. of filled pods	No. of unfilled pods	Total No. of pods	Shelling %	SMK (%)	100-K.W	*S.litura* damage	LLS damage	Pod yield
Days to 50 % flowering	TKG-19A x J-11	0.227*	0.182	0.272**	0.144	0.044	0.102	-0 179	-0.260	0.218*
	J 11 x TGLPS3	0.219*	-0.090	0.234*	0.063	0.080	0.246*	-0.319**	-0.330**	0.339**
Number of filled pods	TKG-19A x J-11	-	0.039	0.943**	0.297**	0.310**	-0.212*	-0.660**	-0.670**	0.785**
	J 11 x TGLPS3	-	-0.016	0.838**	0.240*	0.388**	0.254**	-0.481**	-0.570**	0.683**
Number of unfilled pods	TKG-19A x J-11		-	0.368**	-0.393**	-0.330**	-0.050	-0.255**	-0.280**	0.012
	J 11 x TGLPS3		-	0.531**	-0.230*	-0.322**	-0.400	-0.04	-0.125	0.002
Total number of pods	TKG-19A x J-11			-	0.146	0.176	0.214*	-0.701**	-0.710**	0.820**
	J 11 x TGLPS3			-	0.070	0.153	0.211	-0.430**	-0.550**	0.583**
Shelling (%)	TKG-19A x J-11				-	0.417**	0.097	-0.058	-0.026	0.060
	J 11 x TGLPS3				-	0.453**	0.656**	-0.217	-0.234*	0.211
SMK (%)	TKG-19A x J-11					-	0.273**	-0.271**	-0.206*	0.230*
	J 11 x TGLPS3					-	0.649**	-0.278**	-0.270*	0.396**
100-kernel weight (g)	TKG-19A x J-11						-	-0.210	-0.166	0.224*
	J 11 x TGLPS3						-	-0.451**	-0.425**	0.568**
S.litura damage	TKG-19A x J-11							-	0.809**	-0.840**
	J 11 x TGLPS3							-	0.770**	-0.743*
Late leaf spot (LLS)	TKG-19A x J-11								-	-0.805**
	J 11 x TGLPS3								-	-0.771

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

Table 2 Direct and indirect effects of different traits towards pod yield in two F_2 populations of groundnut

Character	F_2 Population	Days to flower	No. of filled pods	No. of unfilled pods	Total No.of pods	Shelling (%)	SMK (%)	100-K.W (g)	*S.litura* damage	LLS damage	'r' value
Days to 50% flowering	TKG 19A x J 11	0.0264	0.1115	0.0488	-0.0609	-0.0103	0.0253	0.0264	0.0329	0.0180	0.218**
	J 11 x TGLPS 3	0.0514	0.0278	0.0377	0.0427	0.0127	0.0354	0.0394	0.0461	0.0455	0.339**
Number of filled pods	TKG 19A x J 11	0.0814	0.4674	0.0862	-0.2116	0.0111	0.0939	0.0744	0.1158	0.0670	0.785**
	J 11 x TGLPS 3	0.0812	0.0466	0.078	0.1282	-0.0056	0.0813	0.0825	0.0948	0.0963	0.683**
Number of unfilled pods	TKG 19A x J 11	-0.0096	-0.0076	-0.040	0.0267	0.0768	-0.0108	-0.0150	-0.0062	-0.0020	0.012
	J 11 x TGLPS 3	-0.0098	-0.0077	-0.041	0.0238	0.0746	-0.0114	-0.0162	-0.00642	-0.0041	0.002
Total number of pods	TKG 19A x J 11	0.0821	0.4462	0.1326	-0.2285	0.047	0.0888	0.0749	0.1185	0.0666	0.820**
	J 11 x TGLPS 3	0.0635	0.0353	0.0438	0.1217	0.0359	0.0627	0.0611	0.0768	0.0794	0.583**
Shelling (%)	TKG 19A x J 11	0.0288	0.1434	-0.0263	-0.0170	-0.2056	0.0461	0.0313	0.0315	0.0279	0.060
	J 11 x TGLPS 3	0.0686	0.0502	0.0655	0.062	-0.2882	0.0621	0.0705	0.0654	0.0653	0.211*
SMK (%)	TKG 19A x J 11	0.0284	0.1486	-0.0188	-0.0264	-0.0692	0.0707	0.0366	0.0428	0.0242	0.230*
	J 11 x TGLPS 3	0.0572	0.0438	0.0664	0.0651	-0.1011	0.0657	0.0685	0.0658	0.0647	0.396**
100-K.W (g)	TKG 19A x J 11	0.0247	-0.0576	0.0173	0.0908	0.0016	0.036	0.0542	0.0356	0.0210	0.224*
	J 11 x TGLPS 3	0.0851	0.0731	0.0944	0.0806	-0.1461	0.0874	0.1006	0.0972	0.0949	0.568**
S.litura damage	TKG 19A x J 11	-0.0814	-0.337	-0.1165	0.1363	-0.0673	-0.0924	-0.0872	-0.134	-0.0643	-0.840**
	J 11 x TGLPS 3	-0.0865	-0.0662	-0.0795	-0.1074	-0.0061	0.0839	-0.0899	-0.117	-0.1066	-0.743**
Late leaf spot (LLS)	TKG 19A x J 11	-0.0783	-0.3369	-0.1167	0.1448	-0.0713	-0.0862	-0.0825	-0.1204	-0.057	-0.805**
	J 11 x TGLPS 3	-0.0904	-0.0671	-0.0807	-0.1183	-0.0039	-0.0875	-0.0931	-0.1127	-0.1176	-0.771**

Residual effect = 0.0166; Residual effect = 0.0102; * Significant at 5% level; ** Significant at 1% level

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Heterosis and combining ability for seed yield, oil content, other agronomic traits involving mutant restorer lines in sunflower, *Helianthus annuus* L.

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Abstract

Evaluation of parents and F_1s derived from crossing four females and eight testers in a line x tester fashion revealed that variance due to SCA had higher magnitude than GCA variance for capitulum diameter, seed filling (%), 100-seed weight, volume weight, oil content and seed yield indicating that the these traits are under the influence of non-additive gene actions. However, GCA variance had higher magnitude for hull content implying that additive gene action is responsible in controlling its inheritance. The lines DSF 15A and (CMS 4546A x NDOL-2) revealed significant GCA effects for seed yield/plant. The tester MR-265-2 showed good general combining ability for both for seed yield and oil content. The line CMS 4546A performed as good general combiner for characters like 100-seed weight, seed filling (%) and volume weight, while MR 265-2 for seed yield, oil content, 100-seed weight and seed filling (%). The hybrids (CMS 4546A x MR 6D-1-8) recorded good specific combining ability for capitulum diameter, oil content and seed yield followed by (CMS 4546A x NDOL-2) x MR 6D-1-4 for 100-seed weight, oil content and seed yield and (DSF 15A x MR 265-2) for oil content and seed yield. The hybrids (DSF 15A x MR 265-2), (4546A x MR 6D-1-8), (4546A x NDOL2-2) x MR 6D-1-4 exhibited significant better parent as well as standard heterosis over MSFH 17 and KBSH 1 for seed yield.

Key words: Heterosis, general and specific combining ability, gene action

Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important edible oilseed crops, which ranks next only to soybean in the world's production of edible oils. It is a highly cross-pollinated crop, which makes it useful for the development of both hybrids and open pollinated varieties. Ever since the release of first sunflower hybrid in India BSH-1 by Seetharam (1980), many hybrids have been released for cultivation by utilizing CGMS system. Consequently, the hybrids developed possessed a narrow genetic base making the crop not only vulnerable to new pests and diseases but also lowered the magnitude of standard heterosis due to exhaustion of variability in the parental lines. One of the options to diversify the hybrid is through subjecting R lines to mutagenesis and use them in the cross combinations. In the present studies, attempts have been made to utilize mutant R lines of 6D-1 and R 265 in cross combinations to know the extent of heterosis and combining ability.

Material and methods

Experimental material for the present study consisted of four cytoplasmic male sterile (CMS) lines and eight restorer lines ® lines). The four CMS lines *viz.*, CMS 234A, DSF 15A, CMS 4546A and 4546A x NDOL-2 were crossed with eight Restorer lines *viz.*, M 6D-1-4, M 6D-1-8, M 6D-1-9, M 6D-1-10 (mutant derivatives of R line 6D-1), MR-265-2, M R-265-8, MR-265-9 and MR265-10 (mutant derivatives of R line 265) in line x tester design to obtain 32 crosses during *kharif*, 2004. The experimental material consisting of 46 entries *viz.*, 32 hybrids, eight restorers (males), four corresponding maintainer (B) of above A lines and two checks were sown in a Randomized Block Design (RBD) with two replications during summer 2005 at the oilseed block of MARS, UAS, Dharwad. The plot size for each entry consisted of 2 rows of 3 m row length in each replication. The inter and intra-row spacing provided was 60 cm and 30 cm, respectively. All recommended agronomic practices were followed for raising a successful crop. Observations were recorded on five random plants for seven characters and subjected to statistical analysis to derive information on heterosis and combining ability.

Results and discussion

The analysis of variance revealed that the variance due to SCA had higher magnitude than the variance due to GCA for most of the characters except hull content. This indicated that seed yield and its important component traits are under the influence of non-additive gene action. The above findings are in agreement with the earlier reports by Singh *et al.* (1999) and Raghavendra (2004) for seed yield/plant, 100-seed weight, oil content and volume weight. On the contrary, the role of additive gene action

controlling seed filling (%) was reported by Madrap and Makne (1993). Based on the nature of gene actions controlling different traits, it can be concluded that non-additive variance had predominant role in the inheritance of seed yield and other important traits. Hence these characters can be improved through heterosis breeding. The higher GCA variance noticed in respect of hull content indicates that it is predominantly governed by additive gene action. Thus, simple selection can be exercised in the segregating generations of crosses with high *gca* effects for improving hull content. The results obtained in the present study are in conformity with the findings of Merinkovic (1993). However, the studies by Virupakshappa (1991) indicated a predominant role of non-additive gene actions for this trait.

Considering the *gca* effect of parents (Table 1), two CMS lines *viz.*, DSF 15A and (CMS 4546A x NDOL 2) found to be the good general combiners for seed yield/plant. The above results are in accordance with findings of Singh *et al.* (1999) and Raghavendra (2004). Among the testers, none of the mutant lines arising from R line 6D-1 has been a good combiner for seed yield/plant. However, MR 265-2 performed as good general combiner for seed yield, indicating that mutation is responsible for bringing in better general combining ability. For oil content, CMS 234A among the lines and 6D-1-4 and MR-265-9 among the testers were good general combiners. Giriraj *et al.* (1987), Singh *et al.* (1999), Sharma *et al.* (2003) and Raghavendra (2004) also reported that CMS 234A is one of the good general combiners for oil content. None of the CMS lines have been observed as good general combiners for both seed yield and oil content, whereas the tester MR 265-2 fulfilled as a good general combiner for both the traits. The line DSF 15A and tester MR 6D-1-10 observed to be the good general combiner for hull content (Raghavendra, 2004). However, parents exhibiting low *gca* effects for hull content is being considered as desirable, since hull content is inversely associated with oil content. The line CMS 4546A had good general combining ability for a host of traits like 100 seed weight, seed filling (%) and volume weight. Among the R lines, MR-265-2 performed as a good general combiner for seed yield, oil content, 100-seed weight and seed filling (%) and thus can be considered as the best R line in cross combinations. The next best R lines with good GCA are MR 6D-1-8, MR 265-8 and MR 265-10. Thus, the study enabled to isolate potential mutant R lines with high general combining ability.

Considering the *sca* effects of the hybrids (Table 2), CMS 4546A x MR 6D-1-8 had good specific combining ability for capitulum diameter, oil content and seed yield, followed by (CMS 4546A x NDOL-2) x MR 6D-1-4 for 100 seed weight, oil content and seed yield and DSF15A x MR 265-2 for oil content and seed yield. Two crosses DSF 15A x MR 265-8 and CMS 4546A x MR 265-9 showed good specific combining ability for seed filling (%), while CMS 4546A x MR 6D-1-8 for capitulum diameter and six crosses for 100-seed weight. Thus, the present studies enabled to identify lines and testers exhibiting high GCA effects, which in turn reflect on the significant *sca* effects for seed yield and oil content.

Table 1 GCA effects of lines and testers for seed yield and its components in sunflower

	Character	Capitulum diameter (cm)	Seed filling (%)	100-seed weight (g)	Volume weight (g/100 CC)	Hull content (%)	Oil content (%)	Seed yield/ plant (g)
Lines	CMS 234A	0.47	-0.36	-0.03**	-0.18	-0.16	1.45**	-4.77**
	DSF 15A	0.34	-0.48	-0.08**	-0.75**	0.80**	0.04	3.01**
	CMS 4546A	0.15	2.56**	0.20**	0.79**	-0.33	-0.68**	0.22
	(CMS 4546A x NDOL-2)	-0.96**	-1.72**	-0.09**	0.14	-0.31	0.81**	1.54**
GCA lines	CD (P=0.05)	0.57	0.70	0.015	0.53	0.53	0.49	0.75
	CD (P=0.01)	0.76	0.94	0.021	0.70	0.70	0.66	1.01
Testers	M6D-1-4	0.42	-3.04**	-0.45**	-0.66	-0.81*	1.01**	0.30
	M6D-1-8	0.18	-1.24*	0.52**	0.81*	0.14	0.16	0.30
	M6D-1-9	0.01	0.50	-0.45**	-0.19	-0.52	-2.09**	-1.93**
	M6D-1-10	0.33	-2.16**	-0.27**	1.22**	1.71**	-0.47	-0.01
	MR265-2	0.08	2.24**	0.12**	-0.27	0.22	0.82*	2.58**
	MR265-8	-1.60**	1.93**	0.01	-0.97*	-0.22	0.57	0.32
	MR265-9	0.43	0.69	0.16**	-0.68	-0.20	0.81*	-2.33**
	MR265-10	0.15	1.08*	0.36**	0.74*	-0.32	-0.81*	0.77
GCA testers	CD (P=0.05)	0.80	1.00	0.022	0.74	0.75	0.70	1.07
	CD (P=0.01)	1.07	1.33	0.029	0.99	1.00	0.93	1.43

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

Table 2 SCA effects of hybrids for different yield and yield components in sunflower

Crosses	Capitulum diameter (cm)	Seed filling %	100 seed weight (g)	Volume weight (g/100 CC)	Hull content (%)	Oil content (%)	Seed yield/ plant (g)
CMS 234A x M6D-1-4	-0.38	0.09	0.36**	-0.46	-0.30	-2.56**	-2.16*
CMS 234A x M6D-1-8	-1.54	-0.70	-0.82**	0.29	1.33	-0.18	-5.86**
CMS 234A x M6D-1-9	-0.77	1.72	-0.75**	-1.03	-0.35	-1.41*	-2.68*
CMS 234A x M6D-1-10	-0.50	-0.49	-0.48**	0.88	-1.50*	-1.54*	7.19**
CMS 234A x MR265-2	0.85	-0.70	0.43**	0.85	-0.68	-0.88	-3.50**
CMS 234A x MR265-8	0.74	0.83	0.11**	-2.05**	-1.28	3.98**	1.45
CMS 234A x MR265-9	0.30	0.35	0.44**	-0.42	0.46	1.64*	-1.97
CMS 234A x MR265-10	1.29	-1.10	0.70*	1.94*	-0.67	0.95	7.52**
DSF 15A x M6D-1-4	0.80	0.17	0.25**	2.14**	0.07	-4.60**	-2.82*
DSF 15A x M6D-1-8	0.07	1.51	-0.36**	-0.97	-0.06	-1.41*	-2.32*
DSF 15A x M6D-1-9	-0.34	-1.60	0.66**	-0.30	-1.17	0.20	1.24
DSF 15A x M6D-1-10	-0.76	-0.80	-0.13**	0.95	0.41	1.27	-3.58**
DSF 15A x MR265-2	0.79	0.37	-0.46**	-0.71	-1.53*	4.34**	8.41**
DSF 15A x MR265-8	0.28	2.39*	-0.11**	0.79	1.54*	-1.16	-2.70*
DSF 15A x MR265-9	0.24	-1.82	0.10**	0.82	0.44	0.55	1.90
DSF 15A x MR265-10	-1.07	-0.22	0.06**	-2.72**	0.30	0.81	-0.13
CMS4546A x M6D-1-4	-0.66	0.48	-0.09**	-1.13	0.16	1.02	0.04
CMS4546A x M6D-1-8	1.78*	-0.07	1.29**	-0.89	-1.42	2.86**	9.52**
CMS4546A x M6D-1-9	0.65	-1.56	0.31**	-1.05	0.94	-0.48	2.35*
CMS4546A x M6D-1-10	-0.18	-0.08	0.80**	-0.70	-2.33**	-0.36	-0.78
CMS4546A x MR265-2	-0.83	0.38	-0.45**	-0.60	2.83**	-1.69*	-3.17**
CMS4546A x MR265-8	-1.49	-1.91	-0.39**	2.23**	-0.17	-0.14	-1.89
CMS4546A x MR265-9	0.52	2.03*	-0.53**	1.68*	-0.12	-1.13	-1.24
CMS4546A x MR265-10	0.21	0.74	-0.94**	0.46	0.10	-0.07	-4.84**
(CMS4546A x NDOL-2) x M6D-1-4	0.25	0.74	0.52**	-0.55	0.07	6.14**	4.94**
(CMS4546A x NDOL-2) x M6D-1-8	-0.31	0.73	-0.12**	1.57*	0.15	-1.27	-1.34
(CMS4546A x NDOL-2) x M6D-1-9	0.46	1.44	-0.22**	2.39**	0.57	1.69*	-0.91
(CMS4546A x NDOL-2) x M6D-1-10	1.43	1.37	-0.18**	-1.14	0.42	0.62	-2.83*
(CMS4546A x NDOL-2) x MR265-2	-0.81	-0.05	0.49**	0.46	-0.62	-1.77*	-1.74
(CMS4546A x NDOL-2) x MR265-8	0.47	-1.31	0.39**	-0.97	-0.09	-2.67**	3.14**
(CMS4546A x NDOL-2) x MR265-9	-1.06	-0.57	-0.01	-2.08**	-0.78	-1.06	1.30
(CMS4546A x NDOL-2) x MR265-10	-0.43	0.58	0.17**	0.31	0.27	-1.69*	-2.55*
CD (P=0.05)	1.61	0.04	2.01	1.50	1.40	1.50	2.16
CD (P=0.01)	2.17	0.05	2.70	2.02	1.89	2.02	2.91

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

Table 3 Per cent heterosis over better parent and standard checks in sunflower

Crosses	Capitulum diameter (cm)	Seed filling %	100 Seed weight (g)	Vol. Wt (g/100 cc)	Hull Content %	Oil content (%)			Seed Yield (g / plant)		
	BP	BP	BP	BP	BP	BP	MSFH-17	KBSH-1	BP	MSFH-17	KBSH-1
CMS234A x M6D-1-4	-6.41	-1.48	2.41**	-4.41	-2.67	0.67	4.71	-8.65	-2.76	-19.60**	-15.79**
CMS234A x M6D-1-8	-15.38*	-0.19	-2.08**	-4.50	5.30	5.82	13.27*	-1.19	-10.25**	-25.80**	-22.28**
CMS234A x M6D-1-9	-11.54	5.16**	-21.88**	-10.65**	-1.19	-5.82	5.54	-7.93	-8.33**	-24.20**	-20.61**
CMS234A x M6D-1-10	-7.69	-2.93	-11.93**	-2.09	10.66*	-0.83	19.04**	3.85	15.53**	-4.47	0.05
CMS234A x MR-265-2	-0.64	3.62	16.30**	-2.28	-0.63	5.66	6.90	-6.74	-0.85	-18.02**	-14.14**
CMS234A x MR-265-8	-12.18	3.99*	5.96**	-11.39**	-3.87	15.40**	3.42	-9.78*	1.28	-13.52**	-9.42**
CMS234A x MR-265-9	-1.92	3.65	17.51**	-2.94	1.56	12.30**	9.26	-4.69	-15.79**	-23.69**	-20.07**
CMS234A x MR-265-10	2.56	1.65	25.00**	5.63*	-2.30	6.32	5.11	-8.31	17.80**	-2.60	2.02
DSF-15A x M6D-1-4	16.79*	0.63	-18.78**	1.07	5.30	-5.47	9.12	-4.80	3.16	-7.69**	-3.32
DSF-15A x M6D-1-8	9.48	4.76*	-12.22**	-9.09**	7.96	2.82	11.88*	-2.40	4.10	-6.85**	-2.44
DSF-15A x M6D-1-9	5.22	2.97	-11.50**	-10.25**	2.26	0.53	5.97	-7.55	6.60*	-4.62	-0.11
DSF-15A x M6D-1-10	4.48	-3.47	-22.37**	-3.34	14.45**	10.05*	18.61**	3.47	1.15	-9.50**	-5.21*
DSF-15A x MR-265-2	14.18	4.84*	-21.38**	-7.84**	3.51	25.40**	7.27	-6.43	28.45**	14.94**	20.39**
DSF-15A x MR-265-8	-2.24	5.80**	-17.07**	-5.42*	11.93*	-5.40	15.99**	1.19	3.43	-7.45**	-3.07
DSF-15A x MR-265-9	12.69	1.98	-10.51**	-1.09	8.44	4.10	12.38*	-1.97	5.73*	-4.19	0.35
DSF-15A x MR-265-10	0.75	2.62	-7.55**	-8.37**	7.64	7.23	11.55*	-2.69	9.09**	-2.40	2.23
CMS4546A x M6D-1-4	-20.68**	0.06	-11.83**	-9.69**	7.19	24.31**	5.67	-7.81	-3.83	-7.57**	-3.19
CMS4546A x M6D-1-8	-8.22	1.63	34.52**	-5.36*	5.08	24.33**	3.58	-9.64*	12.70**	8.32**	13.46**
CMS4546A x M6D-1-9	-15.58*	1.94	-3.94**	-8.30**	10.80	0.18	9.22	-4.72	-3.69	-7.44**	-3.05
CMS4546A x M6D-1-10	-18.41**	0.47	9.17**	-3.85	7.30	2.12	5.77	-7.73	-5.81*	-9.46**	-5.18
CMS4546A x MR-265-2	-23.51**	6.53**	-7.79**	-7.35**	19.69**	5.49	17.98**	2.92	-5.45*	-9.13**	-4.82
CMS4546A x MR-265-8	-36.83**	3.28	-8.68**	-2.01	8.08	-4.44	6.54	-7.06	-7.15**	-10.75**	-6.53*
CMS4546A x MR-265-9	-13.88*	6.66**	-8.68**	-2.64	8.31	-3.77	6.77	-6.86	-10.64**	-14.12**	-10.05**
CMS4546A x MR-265-10	-17.28**	5.53**	-12.72**	-2.14	8.65	5.88	7.10	-6.57	-11.51**	-14.96**	-10.93**
(CMS4546A x NDOL-2) x M6D-1-4	11.29	8.42**	15.56**	-3.76	-11.36*	34.93**	5.47	-7.99	29.47**	5.03**	10.00**
(CMS4546A x NDOL-2) x M6D-1-8	4.84	-2.23	13.29**	-0.43	-5.23	4.60	8.89	-5.01	13.81**	-7.67**	-3.30
(CMS4546A x NDOL-2) x M6D-1-9	9.68	2.76	-10.52**	-1.23	-3.67	7.17	8.10	-5.70	10.11**	-10.67**	-6.44*
(CMS4546A x NDOL-2) x M6D-1-10	20.16*	-2.30	-5.65**	-6.37*	4.56	5.13	15.00**	0.32	10.08**	-10.70**	-6.47*
(CMS4546A x NDOL-2) x MR-265-2	-6.91	2.73	17.72**	-2.44	-8.70	4.76	6.60	-7.00	16.03**	-4.52	0.00
(CMS4546A x NDOL-2) x MR-265-8	-3.23	-0.41	10.73**	-7.71**	-9.62*	-12.86**	6.90	-6.74	16.97**	-0.12	4.61
(CMS4546A x NDOL-2) x MR-265-9	0.81	0.43	6.58**	-6.57*	-11.85*	-3.93	4.68	-8.68	1.91	-7.64**	-3.26
(CMS4546A x NDOL-2) x MR-265-10	3.63	2.06	11.97**	2.15	-10.08*	-0.55	7.76	-5.99	12.31**	-8.89**	-4.58
CD (P=0.05)	2.11	2.97	0.07	1.98	3.34	2.28	2.28	2.28	2.98	2.98	2.98
CD (P=0.01)	2.82	3.96	0.09	2.64	4.45	3.03	3.03	3.03	3.98	3.98	3.98

*, ** Significant at 5 and 1% level

The studies on heterosis (Table 3) revealed that 14 hybrids exhibited better parental heterosis, out of which three hybrids DSF 15A x MR 265-2, CMS 4546A x MR 6D-1-8, (CMS 4546A x NDOL2-2) x MR 6D-1-4 exhibited significant better parent as well as standard heterosis over MSFH 17 and KBSH 1 check hybrids for seed yield. The above results are in accordance with the earlier reports of Gill and Punia (1996), Nehru *et al.* (2000), Kumar *et al.* (2001) and Mohanrao (2001) for standard heterosis. The hybrid DSF 15A x MR 265-2 exhibited 28.45% higher over better parent (DSF15A). The higher heterobeltiosis of this hybrid may be attributed to the fact that seed yield/plant is mainly governed by non-additive gene actions as also seen from the higher *sca* effects. Considering the *gca* status of the parents involved in this hybrid combination, both the parents turned out to be good general combiners for seed yield with high x high *gca* effects. The hybrid DSF 15A x MR 265-2 can be considered as superior, since it involved both parents with high GCA effects resulting in high SCA and heterobeltiosis and standard heterosis. The above results are in agreement with the findings of Vishwanath (2003). The next best hybrids were CMS 4546A x MR 6D-1-8 exhibiting heterobeltiosis of 12.70% and standard heterosis of 13.46% over KBSH-1 followed by (CMS 4546A x NDOL-2) x MR 6D-1-4 with better heterosis of 29.47% and standard heterosis of 10.00% over KBSH-1. However, the heterotic effects in the first hybrid as a result of low GCA in both the parents has reflected in the form of significant *sca*. Whereas, in the latter hybrid (CMS 4546A x NDOL-2) x MR 6D1-4, the parents were characterized by high x low *gca* effects, which in turn reflected significantly on *sca* effects also. The hybrid CMS 4546A x MR 6D-1-8 manifested heterosis as a result of cross between parents exhibiting low x low *gca* effects for seed yield but significantly ended up in high *sca*. The reports of Viswanath (2003) also confirm the above findings with the present studies. Eleven hybrids expressed superior heterobeltiosis, however, these hybrids did not end up in appreciable magnitude of standard heterosis over MSFH-17 or KBSH-1. The present findings revealed that it is possible to obtain considerable magnitude of heterobeltiosis as well as standard heterosis over the leading commercial check hybrid using mutant R lines. None of the mutant MR 6D-1 restorer lines have been able to bring about superior heterosis in combination with CMS 234A indicating a trivial genetic changes that perhaps was not sufficient to derive hybrids surpassing KBSH 1. However, it could be seen that testers MR 6D-1-8 and MR 6D-1-4 nicked well with other A lines CMS 4546A and (CMS 4546A x NDOL-2), respectively, resulting in

superior heterotic hybrids over MSFH-17 and KBSH-1. Considering the extent of heterosis of hybrids for oil content, seven hybrids exhibited significant positive heterosis (Gangappa *et al.*, 1997; Nehru *et al.*, 2000; Vishwanath, 2003 and Raghavendra, 2004). Out of these, once again three hybrids CMS 234A x MR 265-8, DSF 15A x MR 265-2 and CMS 4546A x NDOL 2 x MR 6D-1-4 have also shown significant standard heterosis over the check hybrid. Madrap and Makne (1993) and Raghavendra (2004) have also reported standard heterosis for this trait. As sunflower is primarily grown for its oil, heterobeltiosis for both seed yield and oil content is essential to realize higher oil yield/ha. It is interesting to note that two of the three hybrids *viz.*, DSF 15A x MR 265-2 and (CMS 4546 x NDOL-2) x MR 6D-1-4 have also recorded superior heterosis both for seed yield/plant and oil content. The parents involved in these two crosses observed to have either high x high or high x low *gca* effects, leading to significant *sca* effects. Thus, these hybrids can be further evaluated in large scale over locations for assessing their superiority over check hybrids. With respect to other traits, the hybrid CMS 4546A x NDOL-2 x MR 6D-1-4 which exhibited superior standard heterosis for seed yield also had better parent heterosis for 100-seed weight, seed filling (%) and low hull content. The hybrids 4546A x MR6D-1-8 and DSF 15A x MR 265-2 were heterotic only for seed filling. Further, the study also revealed that superior heterosis over check hybrids is probably due to change in the genetic constitution of the restorers MR 6D-1, out of which M6D-1-8 and R265-2, R265-4 nicked well in the hybrid combinations than their parental lines in the check hybrids. Therefore, subjecting R lines of leading hybrids to mutagenic effects would be of interest in their diversification to obtain higher standard heterosis.

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Genetic diversity among the gamma ray induced mutants of groundnut, *Arachis hypogaea* cultivar, TAG 24

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Abstract

Cultivated groundnut is known to be vulnerable to several stresses due to its narrow genetic base. The present study was carried out to generate genetic variability through gamma ray mutagenesis in groundnut using the most popular, highly productive and widely adapted Trombay groundnut cultivar, TAG 24. In all, 77 true breeding mutants for various characters were isolated. High yielding potential along with different yield contributing parameters of these induced mutants were ascertained across the seasons. Mutant TGM 16 produced consistently higher yields across the four generations apart from its superiority in seed size, shelling percentage and oil content. Besides, five mutants distinctively showed an improvement for shelling percentage and nine mutants for seed size compared to parent. Induced mutants were genetically diverse both in rainy and summer seasons due to greater genetic variability created for plant height, pod and seed yield and seed size through gamma ray mutagenesis.

Key words: *Arachis hypogaea*, induced mutagenesis, gamma rays, yield potential, genetic diversity

Introduction

Plant evolution under domestication has led to increased productivity, but at the same time, it has narrowed the genetic base of crop species. The challenges that face modern plant breeders are to develop higher yielding, nutritious and environmentally friendly varieties that improve our quality of life without harnessing additional natural habitats for agricultural production. In spite of significant morphological variation, lack of variability at genetic or molecular level is often cited as one of the reasons for low progress in cultivated groundnut (*Arachis hypogaea* L.). This is possibly because tetraploidy of *A. hypogaea* which could not cross with its diploid wild relatives. Therefore, all the modern groundnuts are probably derived from a single plant. The scarcity of genetic diversity makes groundnut vulnerable to a wide variety of biotic and abiotic stresses. For instance, groundnut cultivars grown in the Southern USA are highly susceptible to *Meloidogyne arenaria* and damage in heavily infested fields can be devastating (Nelson *et al.*, 1989). In contrast to cultivated groundnuts, wild *Arachis* species have high genetic diversity and are rich source of genes for pest and disease resistance and other characteristics of interest (Singh and Simpson, 1994; Chandran *et al.*, 2000).

In groundnut, induced mutagenesis using both physical and chemical mutagens has been extensively used to generate genetic variability for breeding and genetic experiments. Earlier studies reported greater genetic variance for various morphological and yield traits among radiation induced mutants (Gregory, 1955; Patil, 1966). Even though macro-mutations are generally deleterious, the diversified background created by the irradiation could be valuable source of germplasm that could be stabilized in normal appearing phenotypes (Emery *et al.*, 1970).

Genetic improvement of groundnut using both mutation and recombination breeding at the Bhabha Atomic Research Centre (BARC), Mumbai played a significant role in creation of unique traits (Murty *et al.*, 2004). The groundnut cultivar, Trombay Akola Groundnut (TAG) 24 was released in 1991 for rainy and *rabi*/summer situations for commercial cultivation in the Vidharbha region of Maharashtra (Patil *et al.*, 1995). It has most of the ideal morpho-physiological traits of groundnut, such as semi-dwarf habit, small, thick, dark-green leaves, determinate flowering, early maturity and enhanced dry matter partitioning (Kale *et al.*, 2002). TAG 24 showed consistent superiority in the All India Coordinated Research Project on Groundnut *rabi*/summer varietal trials surpassing many check varieties with a yield advantage upto 25% (Kale *et al.*, 1999). In view of the worthiness of TAG 24, it was subjected for radiation based induced mutagenesis to generate genetic variability for different agronomic traits. Isolation of economically important induced mutants and assessment of their genetic diversity is reported in the present study.

Material and methods

Seeds (500 each) of TAG 24 were treated with 150, 250 and 350 Gy gamma rays during rainy season 2000. After harvesting all the M_1 plants dose-wise individually, they were advanced to M_2 generation as plant to row progenies during summer 2001. All throughout the crop season, a

total of 11,441 M_2 plants were screened for variants at regular intervals, harvested separately and advanced to the M_3 to study the breeding behaviour. Based on the M_3 and M_4 studies, 77 true breeding mutants for various morphological traits were isolated with a mutation frequency of 0.72%.

From M_5 to M_8 generations, data on plant height, number of branches, pod yield (g/plant), seed yield (g/plant), 100 seed weight (HSW in g), shelling percentage, oil percentage and oil yield (g/plant) were collected from five randomly selected plants in two replications from 77 mutants and parent, TAG 24. Seed oil content was estimated by Nuclear Magnetic Resonance Spectrometer (Oxford MQA 6005 Model, Oxford Instruments UK Ltd., Oxan, UK). The spacing between the lines and hills was 50 x 15 cm and 30 x 10 cm in rainy (June-October) and summer (January-May) season, respectively. Groundnut crop received more than 2,000 mm rainfall during rainy season, while summer crop was raised under irrigation. Such contrasting seasons facilitate to study mutant x environment interaction. Mean values over two rainy (M_5 and M_7) or two summer (M_6 and M_8) seasons were estimated. These mean values were used for estimation of Euclidean distance which is a measure of dissimilarity for various mutant combinations and expressed as percentage. Euclidean distances were computed as: Distance $(x, y) = [\Sigma_i (x_i - y_i)^2]^{1/2}$. Mutants were clustered by Complete linkage method using Euclidean distances for both rainy and summer seasons. In Complete linkage method, the distances between clusters are determined by the greatest distance between any two genotypes in the different clusters. Estimation of Euclidean distances and cluster analysis was performed by Statistica (1996).

Results and discussion

Performance of TAG 24 mutants: A total of 77 stabilized induced mutants of TAG 24 were evaluated from M_5 to M_8 generations in two rainy (June - September 2002 and 2003) and two summer (January - May 2003 and 2004) seasons. Significant differences were observed for all the characters in each generation as well as for rainy and summer seasons and across generations from the pooled analysis. Mutants TGM 59 and TGM 93 in M_5 generation recorded superior pod (41.4-42.1 g/plant) and seed (29.8-30.6 g/plant) yield over TAG 24 (36.7g; 26.0g). Similarly, TGM 16 in the M_6 had greater pod (38.4 g/plant) and seed (27.8 g/plant) yield over TAG 24 (31.8 g; 21.9 g). But in M_7 generation, none of the mutants produced superior pod and seed yields. While in the M_8, TGM 7, TGM 16, TGM 30, TGM 49, TGM 79, TGM 84, TGM 88, TGM 90 and TGM 94 had surpassed the pod (36.1 - 41.4 g/plant) and seed (25.6 - 30.4 g/plant) yield of TAG 24 (32.5 g; 23.0 g). Among these, TGM 30, TGM 84 and TGM 90 were high yielding partly due to increased shelling percentage and seed size, while in TGM 88 due to higher shelling percentage and in TGM 94 due to improved seed size. From pooled performance during summer, TGM 16, TGM 79, TGM 84 and TGM 94 registered 6.5 to 17.4% yield superiority over TAG 24. Mutant TGM 16 produced consistently higher pod and seed yields with 6.1% and 7.3% increase over TAG 24 based on pooled mean across the four generations apart from its superiority in seed size, shelling percentage and oil content. While, TGM 84 and TGM 94 specifically adapted to summer because of their yield superiority of 12.0 to 15.6% over TAG 24 in summer. Besides, TGM 8, TGM 54, TGM 55, TGM 70 and TGM 73 consistently showed a significant improvement in shelling percentage of 76.0-77.4% compared to 71.3% in TAG 24 based on pooled mean over four generations. Further, TGM 59, TGM 61, TGM 64, TGM 65, TGM 70, TGM 85, TGM 91, TGM 92 and TGM 93 recorded significantly superior HSW (61.8-75.3 g) in all the four generations over TAG 24 (55.6 g). Since shelling out turn and HSW are important yield contributing factors in groundnut, the mutants showing improved shelling percentage and HSW would be ideal genotypes to evolve suitable recombinants.

An estimation of oil content in large seed TAG 24 mutants in M_5, M_6, M_7 and M_8 generations revealed that mutant TGM 65 recorded superiority for both oil content and HSW in all the four generations; TGM 59 and TGM 94 in three generations and TGM 16, TGM 30, TGM 63, TGM 64, TGM 70, TGM 80, TGM 92 and TGM 93 in two generations. In M5 generation, TGM 16, TGM 59, TGM 89 and TGM 93 recorded superior oil yield (14.2 - 15.0 g/plant) over TAG 24 (12.9 g). Similarly, TGM 16 in the M_6 had greater oil yield (13.3 g/plant) over TAG 24 (10.2 g). In the M_8, TGM 7, TGM 16, TGM 30, TGM 79, TGM 84, TGM 88, TGM 90 and TGM 94 had surpassed the oil yield (12.6 - 15.1 g/plant) of TAG 24 (11.1g). TGM 16 showed consistent superiority for oil yield across the generations. Earlier, high yield potential in groundnut mutants induced by X-rays, gamma rays and EMS were demonstrated due to mutation for seed size (Mouli *et al.*, 1987; Hussein *et al.*, 1991; Branch, 2002; Gowda *et al.*, 2002). Prasad *et al.* (1984) isolated promising high yielding EMS mutants with increased pod number/plant and shelling percentage. Thus, it is evident from these studies that it is possible to induce genetic variability for various traits. This variability would be effectively utilized to evolve useful groundnut genotypes.

Genetic diversity among TAG 24 mutants: In order to identify distinct mutants as they are likely to contain the large number of agronomically useful alleles, genetic diversity among 77 TAG 24 mutants along with parent was estimated from the pooled mean values over two rainy or two summer seasons separately. Dendrograms for both rainy and summer seasons revealed that mutants were well dispersed from the parent in both the directions due to greater genetic variability for different traits generated through induced mutagenesis (Fig. 2 and 3).

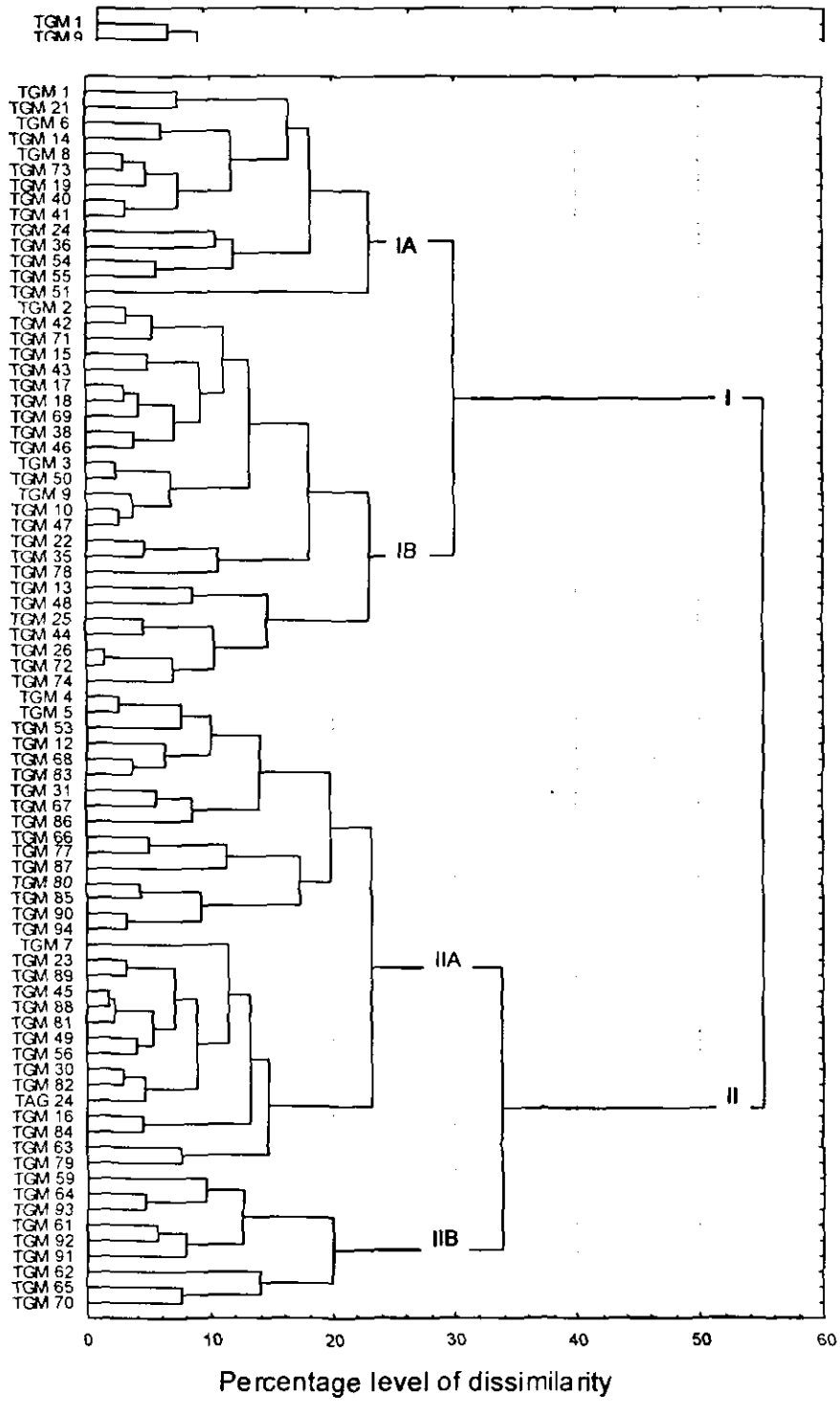

Fig. 1 Dendrogram depicting the genetic diversity among TAG 24 mutants during rainy season

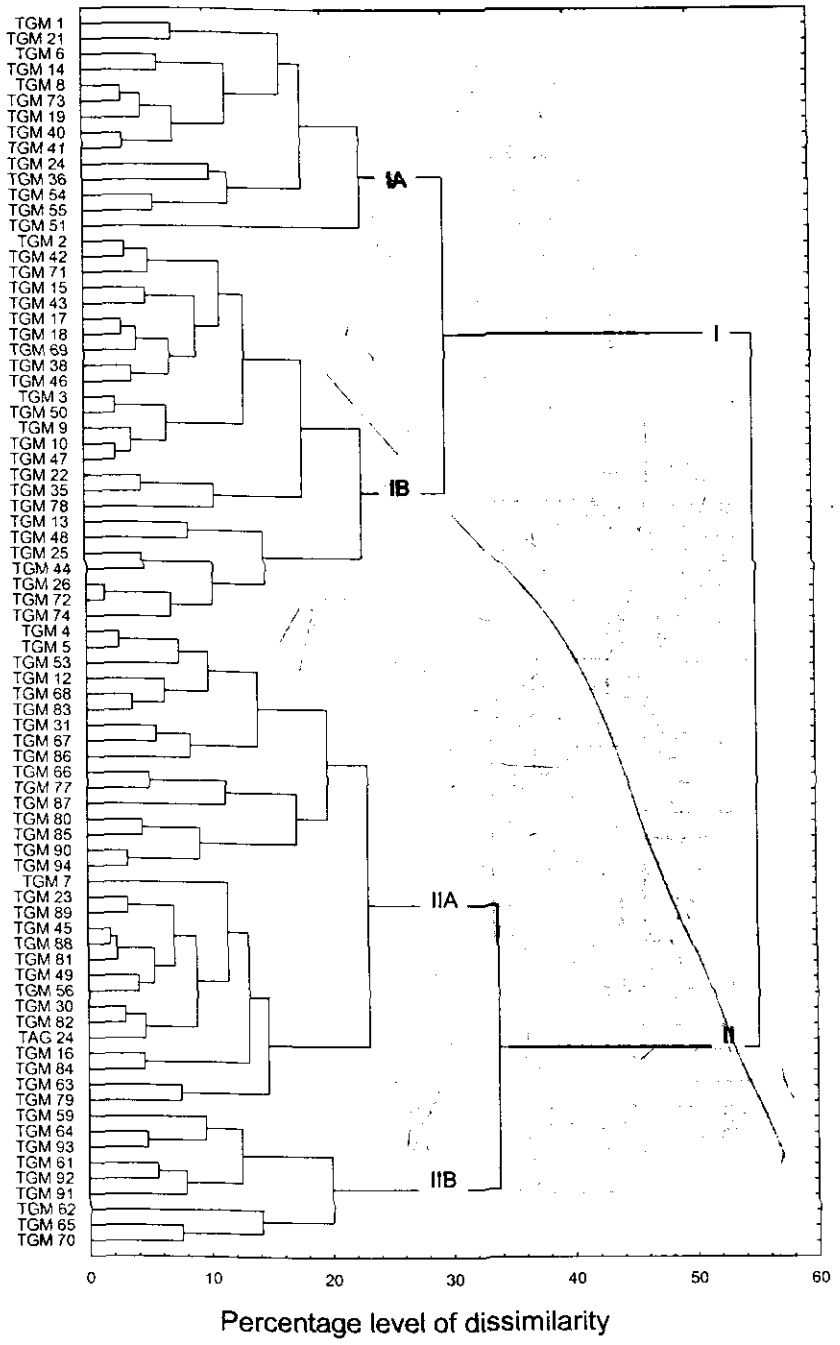

Fig. 2 Dendrogram depicting the genetic diversity among TAG 24 mutants during summer season

Fig. 2 Dendrogram depicting the genetic diversity among TAG 24 mutants during summer season

Rainy season: In rainy season, cluster analysis of induced mutants created two genetically diverse clusters one with 65 mutants and parent and other with 12 mutants each at 68% dissimilarity level (Fig. 1). Basis for clustering was mainly due to differences in plant height and HSW in mutants. Mutants in cluster II were taller with higher HSW than cluster I. Cluster I was divided into two sub-clusters IA and IB at 50% level of dissimilarity with 8 and 58 genotypes, respectively. It was the shorter plant height of the mutants in cluster IA separated them from cluster IB. Further, cluster IB was divided into two clusters IB_1 and IB_2 at 36% dissimilarity with 42 and 16 genotypes, respectively due to differences in plant height, pod yield, seed yield and HSW. Genotypes in cluster IB_2 had greater pod yield, seed yield and larger seed size than IB_1 cluster. Similarly, cluster II having taller mutants with higher HSW was divided into two sub-clusters, IIA and IIB at 40% dissimilarity with five and seven mutants each, respectively. Mutants of cluster IIB had higher pod and seed yields than cluster IIA.

Summer season: During summer season, TAG 24 mutants were grouped into two genetically diverse clusters one with 38 mutants and other with 39 mutants and parent at 55% dissimilarity based on plant height, pod yield, seed yield and HSW (Fig. 2). Genotypes in cluster II were taller with more pod yield, seed yield and HSW than cluster I. Based on the HSW, cluster I was divided into sub-clusters IA and IB at 30% dissimilarity with 13 and 25 mutants respectively. Mutants in cluster IA had smaller seed size than cluster IB. In cluster IA, lower shelling percentage in TGM 51 separated it from rest of the genotypes. Cluster IB divided into two groups having 18 and 7 mutants with higher HSW in latter group. Similarly, cluster II was divided into IIA and IIB at 34% dissimilarity with 31 and 9 genotypes respectively, where in cluster IIB had genotypes with larger seed than IIA apart from their higher pod yield, seed yield and plant height. In cluster IIB, slightly taller height in TGM 62, TGM 65 and TGM 70 separated them from rest of the genotypes in the cluster.

Induced mutagenesis generated greater genetic variability particularly for plant height, pod yield, seed yield and HSW. As a result, these traits played an important role in creating genetically diverse clusters in both rainy and summer seasons. Rameshkumar Sah *et al.* (1999) observed wide range of genetic differences in the induced mutants in groundnut leading to diverse mutant clusters. TAG 24 mutants were more genetically diverse in rainy season (i.e., 68% dissimilarity) than summer (55%) because of increased genotypic variability for plant height in rainy season. Clustering pattern for seven mutants (TGM 59, TGM 61, TGM 64, TGM 65, TGM 91, TGM 92 and TGM 93) was almost similar in both seasons by virtue of their higher HSW and taller plant height. However, clustering pattern in TGM 62, TGM 63, TGM 66, TGM 70, TGM 85, TGM 86 and TGM 87 had deviated because of significant mutant-season interactions. The proportionate increase in plant height was more in TGM 63, TGM 66, TGM 85, TGM 86 and TGM 87 in rainy season than summer. Similarly, increased HSW in TGM 62 and TGM 70 during summer than rainy season clubbed them in cluster IIB along with others. Although, all mutants originated from the same parent TAG 24, their grouping into distinct clusters indicated wide genetic variability induced by gamma ray mutagenesis, which is comparable to the working germplasm lines. While studying the genetic diversity in mutant based groundnut germplasm, Badigannavar *et al.* (2002) elaborated differences in clustering patterns between seasons owing to differential responses of the genotypes to the seasons. On the other hand, Nadaf (1993) did not find any relationship with clustering pattern and taxonomical varieties among EMS induced mutants having taxonomical importance. Thus in the present study, it is possible to isolate diverse groundnut mutants which may not be useful directly as varieties but by involving them in hybridization with other mutants, breeding lines or cultivars they may be useful to recover ideal recombinants in future.

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Analysis of genetic divergence in water use, efficient germplasm of groundnut, *Arachis hypogaea* L.

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Abstract

An analysis of genetic divergence was carried out in 100 accessions of water use efficient groundnut germplasm. The germplasm were grouped into seven clusters. Among the 15 characters considered, the contribution of chlorophyll content was maximum (24.2%) followed by 100-kernel weight (19.8%), haulm yield/plant (12.6%) and shelling per cent (11.6%). The maximum inter-cluster distance was between IV and VI (D-694.0). The maximum intra-cluster distance was reported in cluster VI (D-123.7) followed by cluster VII (D-104.4). The cluster VII has showed the highest cluster mean for six characters viz., pod yield/plant, shelling per cent, kernel yield/plant, haulm yield/plant, oil content and oil yield/plant. The accessions JAL-36, JAL-36, ICG-3138, ICG-3170, ICG-1448 and ICG-1789 could be used in breeding programme with accessions in cluster VII to develop drought tolerant cultivars.

Key words: Diversity, D^2, groundnut, geographic origin, water use efficient

Introduction

Groundnut is the important oilseed crop grown under rainfed situation in Southern Karnataka. It accounts more than 1/3 of the total area and production of groundnut in Karnataka. In addition to the pests and diseases, the moisture stress is the major limitation to achieve the potential. This situation warrants identification of diverse water use efficient parents to be used in drought tolerant breeding programme. A broad spectrum of variability in segregating generations can be generated by crossing genetically diverse parents. For this, precise information about the extent of genetic divergence is very crucial. D^2 statistic developed by Mahalanobis (1936) is a power tool in quantifying the degree of divergence among biological populations and accessing the relative contribution of different components to the total divergence at intra and inter-cluster levels. In the present investigation, an attempt was made to ascertain the nature and magnitude of genetic divergence in 100 water use efficient germplasm accessions of groundnut and identify the potential parents to be considered for drought tolerant breeding in southern Karnataka.

Material and methods

The material consisted of diverse water use efficient germplasm accessions of groundnut obtained the Indo-Australian project and the available germplasm with the AICRP on Groundnut, Agricultural Research Station, Chintamani. These germplasm accessions were from 13 countries of the world representing diverse agroclimatic conditions. The material was evaluated in 10 x 10 simple lattice design with two replications during *kharif* 2004-05 at All India Coordinated Research Project on Groundnut, Agricultural Research Station, Chintamani representing the Southern Karnataka. Each accession was sown in a row of 2.50 m length with a spacing of 30 x 10 cm. The recommended cultural practices were followed in raising the crop. Observations were recorded on ten randomly chosen plants in each accession and replication for 15 metric traits (Table 2). Leaf area was measured and dry weight of the leaves was recorded after oven drying at 80°C for 48 hrs and SLA was calculated using the formula *SLA (cm^2/g) = leaf area (cm^2)/oven dry weight (g) and the* total chlorophyll content estimated utilising the 3rd or 4th leaf from the top on main axis at 70 DAS using SPAD chlorophyll meter and expressed as milligram chlorophyll/gram weight of the leaf tissue. D^2 values among 100 germplasm accessions were computed utilising the varietal means and variances in respect of 15 characters. Group constellations was determined as per the Tocher's method (Rao, 1952) and contribution of characters for genetic divergence was estimated as per Singh and Chaudhary (1977).

Results and discussion

The genetic divergence was studied in 100 water use efficient germplasm of groundnut by using Mahalanobis D^2 analysis. Based on the analysis the 100 accessions were grouped into seven clusters (Table 1). The germplasm accessions included in a cluster were from diverse geographical origin indicating that the geographic diversity need not be necessarily related to genetic diversity. The absence of correlation between genetic diversity and geographical diversity has also been reported by Nayak and Patra (1997) and Venkataravana *et al.* (2000). The random pattern of distribution of genotypes into various clusters from different eco-geographic regions suggests that forces other than geographic influence such as

exchange of breeding material, common parentage, genetic drift, natural and artificial selection are responsible for diversity as reported earlier (Murthy and Arunachalam, 1966). Contribution towards genetic divergence is represented in Table 2 it was observed that among all the characters, the chlorophyll content was maximum (24.2%) followed by 100-kernel weight (19.8%), haulm yield (12.6%) and shelling per cent (11.6%). As these characters together accounted for more than 68% of the total divergence, they should be considered in drought tolerance breeding programme. This was also confirmed by Nadaf *et al.* (1986) and Katule *et al.* (1992).

The average intra and inter-cluster distance is presented in Table 3 showed maximum inter cluster distance between cluster IV and VI (D=694.1) followed by cluster V and VI (D=456.8) which suggested that the hybridization programme involving parents from these clusters is expected to give higher frequency of better segregates/desirable recombinants for developing useful drought tolerant genetic stocks/varieties. The maximum intra-cluster distance was reported in cluster VI (D=123.7) followed by cluster VII (D-104.4).

Table 1 Distribution of 100 WUE germplasm of groundnut in different clusters

Cluster No.	Accession No./Name	No. of genotypes
I	JAL-49, JUN-25, TIR-20, JAL-35, TIR-26, JUN-48, TIR-29, JUN-04, ICG-1353, ICG-1465, ICG-2223, ICG-2092, ICG-2239, ICG-1304, ICG-4071, ICG-3256, ICG-3253, ICG-1306, ICR-35, TIR-36, JAL-41, JAL-14, JAL-05, JUN-4, JAL-18, JAL-19, ICR-22, ICR-24, ICG-3763, ICG-328, ICG-2021, ICG-2087, ICR-28, ICG-3089, ICG-3069, ICG-1311, ICG-1208, ICG-3169, TIR-37, ICG-3550	42
II	JAL-38, ICG-3138	2
III	JUN-05, TIR-32, JAL-38, ICR-09, ICR-26, ICR-18, JAL-42, JAL-31, TIR-28, JUN-26, ICG-3556, CTMG-2, ICG-3784, ICG-3310, JL-24, TMV-2, VRI-2, GPBD-4, ICG-2027, ICG-1891	22
IV	JAL-36, ICG-3170	2
V	ICG-1448, CIG-1789	2
VI	CTMG-1, JAL-16, TIR-19, JAL-47, ICR-06	5
VII	CIR-45, JAL-04, JUN-6, JAL-37, ICG-1433, ICG-4047, ICG-3787, ICG-3617, ICG-2022, ICG-1383, ICG-3310, ICG-1204, JUN-33, JAL-41, JAL-17, TIR-12, JAL-08, ICR-25, ICG-3618, ICG-2978, ICG-1768, ICG-1722, TIR-43	25

Table 2 Percentage contribution of each character towards genetic divergence

Character	No. of first rank	Per cent contribution
Plant height (cm)	282	5.7
Number of branches/plant	50	1.0
Days to 50 % flowering	323	6.5
Days to maturity	260	5.3
Number of matured pods/plant	16	0.3
Pod yield/plant (g)	37	0.7
Shelling (%)	572	11.6
Kernel yield/plant (g)	11	0.2
100-kernel weight (g)	978	19.8
Haulm yield/plant (g)	624	12.6
Harvest index (%)	47	0.9
Oil content (%)	41	0.8
Oil yield/plant (g)	430	8.7
Specific leaf area (cm^2/g)	81	1.6
Chlorophyll content (mg/g)	1198	24.2
Total	4950	100

Table 3 Intra-cluster (Diagonal) and inter-cluster distances for seven clusters formed by 100 WUE germplasm of groundnut

Cluster	I	II	III	IV	V	VI	VII
I	(76.03)	188.41	263.81	396.71	176.74	367.30	298.85
II		(27.26)	238.17	331.45	172.65	527.07	249.10
III			(85.19)	299.04	213.11	427.08	323.17
IV				(32.29)	131.07	694.09	340.70
V					(35.22)	456.32	213.37
VI						(123.65)	455.24
VII							(104.44)

(Figures in parenthesis indicate the intra-cluster values)

Table 4 Mean values of seven clusters of water use efficient groundnut germplasm for 15 quantitative characters

Cluster No.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
I	22.2	4.5	37.6	113.5	6.9	5.7	68.8	3.9	30.0	16.3	25.7	41.6	1.7	149.2	7.5
II	18.8	4.7	36.0	108.8	9.3	7.8	67.3	5.2	34.3	21.9	26.3	45.5	2.4	133.5	8.5
III	21.8	5.0	36.8	110.4	7.2	5.5	68.8	3.8	28.6	15.3	26.1	43.3	1.7	156.1	7.3
IV	16.8	4.0	34.5	108.8	4.5	2.9	64.8	1.8	25.5	8.1	26.0	39.9	0.7	171.2	6.3
V	18.3	4.7	36.8	114.8	6.0	4.9	64.5	3.1	26.5	16.6	22.7	37.4	1.2	168.3	6.9
VI	26.5	4.7	37.6	112.1	9.3	8.1	73.0	6.1	34.0	22.4	26.1	45.8	2.8	135.4	8.5
VII	21.3	5.0	35.8	111.3	7.9	6.5	67.3	4.4	27.6	18.7	25.6	42.2	1.9	152.8	7.6

X_1 = Plant height (cm)
X_2 = Number of branches/plant
X_3 = Days to 50% flowering
X_4 = Days to maturity
X_5 = Number of matured pods/plant
X_6 = Pod yield/plant (g)
X_7 = Shelling percentage (%)
X_8 = Kernel yield/plant (g)
X_9 = 100-kernel weight (g)
X_{10} = Haulm yield/plant (g)
X_{11} = Harvest index (%)
X_{12} = Oil content (%)
X_{13} = Oil yield/plant (g)
X_{14} = Specific leaf area (cm^2/g)
X_{15} = Chlorophyll content (mg/g)

The data on the character means for seven clusters indicated that the cluster VI showed the highest cluster mean for six characters *viz.*, pod yield/plant, shelling per cent, kernel yield/plant, haulm yield/plant, oil content and oil yield/plant. So, the genotypes from these clusters can be used as parents in hybridization programme to improve these characters (Table 4). It is well known that crosses between diverse parents usually produced greater heterotic effect than between closely related ones. Therefore for selection of suitable parents, Arunachalam and Bandyopadhyay (1984) stated if m, is the mean of the genetic divergence among parents and s is the standard deviation of their genetic divergence, the crosses would have higher chance of producing higher frequency and magnitude of heterosis if genetic divergence between their parents is not greater than (m+s) and less than (m-s).In the present investigation the results revealed that the genotypes JAL-38, JAL-16, ICG-3138, ICG-3170, ICG-1448 and ICG-1789 could be used in breeding programme with the accessions in the cluster VII to get potential segregates and to effect further selection to develop high yielding drought resistant cultivars for Southern Karnataka.

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Heterosis and inbreeding depression in sesame, *Sesamum indicum* L.

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Abstract

Study of heterosis in 45 F_1s of sesame resulting from 10 x 10 diallel, excluding reciprocals indicated pronounced hybrid vigour for yield and most of the yield components. The highest value of heterobeltiosis recorded by AT-90 x AT-104 (124.45%) for seed yield/plant. None of the hybrids exhibited significant heterosis for earliness. Crosses between low x medium and medium x medium *gca* parents exhibited greater heterosis. High inbreeding depression was accompanied with high heterosis for most of the traits indicating the predominance of dominance gene action.

Key words: Heterosis, inbreeding depression

Introduction

Sesame, although predominantly a self-pollinated crop, its reproductive biology and ease of making crosses, offers a good scope for exploitation of heterosis. The information on inbreeding depression is of immense value to identify potential crosses with least inbreeding depression for their utilization in crop improvement. The present study was undertaken to assess the magnitude of heterosis and inbreeding depression for yield and yield attributing characters in hybrids of sesame.

Material and methods

The experiment was carried out during *kharif*, 2004 at Main Oilseeds Research Station, JAU, Junagadh. The plant material constituting ten parents *viz.*, AT-90, AT-92, AT-104, AT-114, BAVJ-1, ABT-22, ABT-23, AT-34, G.Til-1 and G-Til-2, 45 F_1s excluding reciprocals obtained from 10 x 10 diallel and 45 F_2s were sown in Randomized Block Design with three replications. Each parent and F_1s were grown in a single row, while, F_2s were sown in 2 rows of 4 meter length. Inter and intra-row spacing was adopted of 45 and 15 cm, respectively. Five competitive plants in each row were chosen to record observations for parental lines and F_1s, while, 20 plants were selected for F_2. Mean values of parents and F_1s were used for estimation of heterosis over better parent (BP) as per Fonseca and Patterson (1968). Later inbreeding depression (ID) was calculated.

Results and discussion

The estimates of mean squares were highly significant for all the 12 characters indicating large variation among parents (Table 1). The range of heterosis was high for seed yield/plant, number of effective branches/plant, number of capsules/plant, number of seeds/capsule, harvest index and leaf area index. However, none of the crosses was observed consistently best heterotic for all the traits. These results were in concurrence with Ragiba and Reddy (2000). The cross AT-90 x AT-104 showed higher potential for seed yield/plant, whereas, ABT-23 x AT-34 for number of capsules/plant, number of seeds/plant, oil content and 1000 seed weight and ABT-22 x G.Til-1 for plant height and oil content.

For days to 50% flowering and maturity, none of the hybrids exhibited significant and desired negative heterosis over their better parental values. Similar findings were also reported by Navadiya *et al.* (1995) and Nijagun *et al.* (2003). In case of plant height, dwarfness is considered as desirable attribute; however, no any hybrid expressed heterobeltiosis for dwarfness. Although many high yielders crosses *viz.*, AT-90 x AT-104, AT-90 x ABT-23 and AT-104 x ABT-23 exhibited medium plant height which is more suitable in rainfed condition due to its early maturity and appropriate physiological efficiency. Thirteen crosses recorded significant and positive heterosis for plant height, the highest being 43.13% in cross ABT-22 x G.Til-1. Sodani and Bhatnagar (1990) also reported similar results. Significant and positive heterobeltiosis was recorded by 10 and 12 F_1s for number of effective branches/plant and number of capsules/plant, respectively. The cross ABT-23 x AT-34 showed highest significant and positive heterobeltiosis (101.32%) followed by AT-104 x G.Til-2 (61.70%) for number of effective branches/plant. Whereas, cross ABT-23 x AT-34 showed highest value of heterobeltiosis (71.70%) followed by AT-104 x AT-34 (67.89%) for number of capsules/plant. However, the top yielder cross AT-90 x AT-104 has not recorded significant heterosis for number of capsules/plant, may be due to balancing the positive and negative genes or presence of additive gene action for this trait. Five hybrids each showed significant and positive heterobeltiosis for number of seeds/capsule and length of capsule, respectively. Only two crosses recorded significant and positive heterobeltiosis for 1000 seed weight *viz.*, ABT-23 x AT-34 (18.25%) and AT-104 x AT-34 (13.10%). For oil content, 13 hybrids revealed significant and positive heterobeltiosis, of which cross ABT-22 x G. Til-1 exhibited highest heterobeltiosis (8.96%). Ten crosses

depicted significant heterobeltiosis for harvest index, whereas, none of the hybrids expressed significantly positive heterobeltiosis for leaf area index. For seed yield/plant, 21 crosses exhibited significant and positive heterobeltiosis while, 4 crosses showed significant and negative heterobeltiosis. The highest value of heterobeltiosis was recorded by AT-90 x AT-104 (124.45%) followed by crosses AT-I04 x G.Til-2 (95.51%), AT-90 x G.Til-23 (77.05%) and AT-I04 x ABT-23 (73.67%) indicating considerable dominance in these crosses. Furthermore, the crosses showing heterosis for one or more yield components were also heterotic for seed yield/plant (Table 2). Number of capsules/plant produced heterotic effect in most of the crosses. Similar results were also reported by Singh (2002). Other important characters contributed to yield heterosis in the present study were number of capsules/plant, number of effective branches/ plant, number of seeds/capsule and 1000 seed weight.

High inbreeding depression was recorded for number of capsules/plant, number of effective branches/plant and seed yield/plant (Table 1). The total number of 35, 22 and 22 crosses exhibited significant and positive inbreeding depression for number of capsules/plant, number of effective branches/plant and seed yield/plant, respectively. Low inbreeding depression was recorded for number of seeds/capsule, harvest index and leaf area index. A close relationship between heterotic response and inbreeding depression was observed for seed yield/plant except only one cross (AT-I 04 x ABT-23). The cross AT-I04 x ABT-23 manifested high seed yield and non-significant inbreeding depression suggesting the preponderance of additive gene action and as such single plant selection following pedigree method could be effective. Similar results were recorded by Godawat and Gupta (1985). Specific combining ability (*sca*) was also computed for all the 45 hybrids. Eighteen hybrids recorded significant *sca* for seed yield, out of which, 13 hybrids exhibited significant and positive *sca* effects. The best specific combination of seed yield A T-90 x AT-104 (Table 2) involved the parents having low x medium *gca* effects. The other specific combinations for seed yield were having medium x medium, low x high, medium x high. High x high and high x medium combiners. The best general combiners could not always produce best specific combinations for all the characters. Marked negative *sca* effects in crosses between high x high and high x medium were note worthy which could be attributed to the lack of complementation between favourable alleles of the parents involved indicating the role of high magnitude of non-additive interaction.

These findings are in agreement with earlier findings of Krishnadoss *et al.* (1987) and Reddy and Haripriya (1993). Marked positive *sca* effects in crosses between medium x medium and low x medium could be ascribed to better complementation between favourable alleles of parents involved. Similar results were also reported by Sharma and Chauhan (1985).

Table 1 Range of heterosis and inbreeding depression (ID) along with best heterotic combination for yield and yield components in sesame

Character	Range of heterosis over better parent (%)	Best heterotic cross	CD (P=0.05)	Cross showing		CD (P=0.05)
				Lowest ID (%)	Highest ID (%)	
Days to 50% flowering	-2.38 to 24.60**	-	3.06	ABT-22 x AT-34 (-14.29)**	AT-90 x ABT-22 (17.76)**	3.37
Days to maturity	0.00 to 10.37**	-	2.59	AT-114 x G.Til-1 (-4.56)**	AT-90 x ABT-22 (8.19)**	2.62
Plant height (cm)	-11.05 to 43.13**	ABT-22 x G.Til-1	11.82	G.Til-1 x G.Til-2 (-31.27)**	ABT-22 x ABT-23 (27.88)**	12.66
Effective branches/plant	-38.46** to 101.32**	ABT-22 x G.Til-2	0.82	AT-90 x AT-34 (-7.14)	AT-92 x AT-104 (54.55)**	0.80
Capsules/plant	-17.19 to 71.90**	AB-23 x AT-34	9.49	AT-90 x AT-92 (4.81)	AT-92 x G.Til-1 (55.85)**	9.68
Seeds/capsule	-42.02** to 55.42**	AT-92 x ABT-23	10.51	AT-114 x ABT-22 (-44.85)**	AT-92 x BAVJ-1 (45.73)**	6.96
Length of capsule (cm)	-8.42 to 24.56**	AT-104 x BAVJ-1	0.20	AT-92 x AT-104 (-13.30)**	ABT-23 x G.Til-2 (14.71)**	0.18
1000 seed weight (g)	-11.27* to 18.25**	ABT-23 x AT-34	0.37	AT-92 x AT-114 (-15.75)**	AT-90 x ABT-22 (20.76)**	0.31
Oil content (%)	-7.47** to 8.96**	ABT-22 x G.Til-1	1.02	AT-114 x G.Til-1 (-9.14)**	AT-92 x AT-34 (11.66)**	0.84
Harvest index (%)	-52.47** to 24.89*	AT-104 x ABT-23	6.21	AT-104 x AT-34 (-77.75)**	AT-90 x AT-104 (24.47)**	6.35
Leaf area index (%)	-54.53** to 36.41	AT-114 x ABT-23	0.27	AT-114 x BAVJ-1 (-121.09)**	ABT-22 x G. Til-1 (47.96)**	0.33
Seed yield/plant (g)	-37.40** to 124.45**	AT-90 x AT-104	1.61	AT-104 x ABT-22 (-7.94)	ABT-22 x ABT-23 (53.44)**	1.74

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

Table 2 **Relationship between heterosis and SCA and inbreeding depression for high seed yield/plant along with significant heterosis of component traits in sesame**

Crosses	Mean seed yield/ plant (g)	Heterosis over better parent (%)	SCA	GCA status of the parents		ID	Significant heterosis of component traits										
				P_1	P_2		Days to 50% flowering	Days to maturity	Plant height (cm)	Branches/ plant	Capsules/ plant	Seeds/ capsule	Length of capsule (cm)	1000 seed weight (g)	Oil (%)	Harvest index (%)	Leaf area index (%)
AT-90 x AT-104	8.8	124.5**	2.7**	L	M	47.9**	-	-	-	-	-	-	18.9**	-	-	-	-32.1
AT-104 x G.Til-2	7.2	95.5**	1.7**	M	M	34.5*	-	3.4*	-	61.7**	55.7**	-	-	-	-	-	-
AT-90 x ABT-23	8.4	77.1**	1.8**	L	H	41.5**	-	4.3**	-	47.6**	35.4**	-	-	-	-	-	-
AT-104 x ABT-23	8.2	73.7**	1.3*	M	H	-7.2	-	4.5**	-	-	29.9*	-	13.6**	-	-	24.9*	-33.8*
ABT-23 x AT-34	8.8	64.5**	1.3**	H	H	51.3**	15.7**	-	23.7**	-	71.7**	39.0**	-	18.5**	4.9**	-	-
AT-114 x ABT-23	8.2	58.9**	1.3*	M	H	44.5**	9.5*	7.8**	-	32.6**	46.8**	-21.9**	-	-	-	-	-
AT-104 x G.Til-1	7.1	54.0**	0.6	M	M	37.7*	-	-	-	-	-	-	-	-	-4.5**	19.0*	-35.1*
AT-34 x G.Til-1	8.2	53.7**	1.2	H	M	33.7**	-	-	23.7**	-	31.0*	-	-	-	-3.2**	-	-40.4**

*,** Significant at 5% and 1% level, respectively; L = Low combiner; M = Medium combiner and H = High combiner; ID = Inbreeding depression

The top yielder cross AT-90 x AT-104 exhibited high heterobeltiosis and *sca* effects along with inbreeding depression for seed yield/plant. Moreover, this cross showed significant and positive heterobeltiosis for more capsule length coupled with high inbreeding depression for number of branches/plant. number of capsules/plant and number of seeds/capsule. Likewise. high yielder hybrid ABT-23 x AT-34 also expressed high heterobeltiosis. *sca effects coupled with inbreeding depression for seed yield.* This cross also displayed significant and positive heterobeltiosis as well a inbreeding depression for number of capsules/plant, number of seeds/capsule, 1000 seed weight and oil content. The cross A T-90 x ABT-23 also showed high heterobeltiosis. sea effects and inbreeding depression for seed yield/plant. The cross also recorded *high heterobeltiosis and inbreeding depression for number* of effective branches/plant and number of capsules/plant. Keeping in view, the mean seed yield, heterosis, inbreeding depression and *sca* effects for seed yield and its components recorded in present study, three crosses *viz.*, AT-90 x AT-104, ABT-23 x AT-34 and AT-90 x ABT-23 may be selected for the commercial exploitation of heterosis and getting transgressive segregants in later generations.

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Heterosis for yield determinants over environments in castor, *Ricinus communis* L.

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Abstract

Forty four castor hybrids developed by line x tester mating design (four pistillate lines x 11 male parents) were studied along with parents and a standard check for heterosis of yield determinant characters. Significant desired heterobeltiosis ranged from 18.7 to 39.6% and standard heterosis ranged from 17 to 32.8% for seed yield/plant. Other characters also showed considerable heterosis over better parent and standard check. However, magnitude of heterosis was found to vary substantially from cross to cross and character to character. Five superior hybrids sorted out on the basis of seed yield/plant *per se* showed no indication of yield heterosis over better parents contributed by heterosis arising from yield components. However, effective branches/plant found to be major contributor toward seed yield so far standard heterosis is concerned. The JP 88 x DCS 89, JP 65 x DCS 89, JP 88 x PCS 124, JP 88 x JI 274 and JP 65 x JI 309 were the promising hybrids over standard check (GCH 6), need to be tested in different agroclimatic zones to prove their yield superiority over the environments.

Key words: Heterosis, seed yield, yield determinants, castor

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop of Gujarat state. In Gujarat, the common practice of castor growing is an intercrop under rainfed and as sole crop under irrigated conditions. Yield potential of castor has considerably increased through exploitation of hybrid vigour on commercial scale and systematic varietal improvement programme. Development of new pistillate sources and male combiners and their testing magnitude of heterosis is a continuous process of heterosis breeding programme. In order to assess the extent of heterosis present in F_1 hybrids and to know the possibility of exploiting heterosis at commercial scale, it is essential to evaluate newly developed pistillate as well as inbred lines in cross combinations for seed yield and its components.

Material and methods

The experimental material comprised of 44 hybrids derived from crossing between four pistillate lines and eleven inbreds in line x tester fashion. Pistillate lines (JP 65, JP 82, JP 88 and SKP 72) and inbred lines (JI 244, JI 258, JI 274, JI 285, JI 298, JI 309, SKI 232, DCS 9, DCS 33, DCS 89 and PCS 124) were selected on the basis of desirable agronomic characters and resistance to *fusarium* wilt. The resulting hybrids along with their parents and one standard check (GCH 6) were sown in Randomized Block Design with three replications. The experiments were conducted during two consecutive years i.e., 2002 and 2003 on medium black soil with two different sowing times during *kharif* season at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh. In each season (*kharif*), first experiment was sown, as early sown condition, during third week of July and second, as normal sown condition, during fourth week of August. The same layout was followed in both sowing times as well as years. Two rows of 7.2 m length of each entry were spaced 90 cm apart with plant to plant distance of 60 cm. The recommended package of practices was followed to raise the crop. Five competitive plants selected randomly from each plot were used for recording the data on 12 characters (Table 1). The data were subjected to statistical analysis according design over environments. The superiority of hybrids was estimated over better parent as heterobeltiosis and over standard check (GCH 6) as standard heterosis according to the method of Fonseca and Patterson (1968).

Results and discussion

Significant mean squares of environments (E), genotypes (G), parents (P) and hybrids (H) for all the characters under study indicated differences within the parents, hybrids and environments and also revealing existence of considerable genetic variability in the material studied (Table 1). Barring effective branches/plant, all the traits showed significant mean squares due to parents *versus* hybrids, this may be due to heterotic response of hybrids under study. Mean squares due to interaction of environments with genotypes, parents and hybrids exhibited significant values for most of the characters, suggesting differential behaviour of parents and hybrids

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under four environments. The mean of hybrids for seed yield/plant, capsules/plant, total and effective lengths of primary raceme, shelling per cent and oil content were higher than the mean of parents suggesting the expression of desirable heterosis for these characters. Earliness, which can escape drought and give good yield even in less precipitation is desirable trait for the castor particularly under rainfed condition. Hence, the crosses manifesting heterosis in negative direction are of immense value to identify early hybrids. The mean days to 50% flowering and maturity in hybrids were less than those in parents, depicted the heterosis toward earliness. In addition, the traits like plant height and nodes/plant are indicative of dwarfness. Such dwarf plant type in castor is suitable particularly for intercropping system. These two characters also manifested lesser mean of hybrids over their counterparts. Since increase in number of effective branches and 100-seed weight is desirable, the mean of hybrids was lower than that of parents for these two characters. The narrow range of hybrids than that of parents for all the characters indicated less environmental influence on character expression of hybrids.

The range of significant desirable heterosis in per cent and five top hybrids selected for seed yield *per se* showing heterosis over better parent and standard check (GCH 6) for 12 characters are shown in Table 2. Expression of heterosis for all the traits, except better parent heterosis for plant height and standard heterosis for shelling percentage indicated that parents used in crossing were genetically divergent. In general, range of heterosis for most of the traits was wider for standard heterosis than better parent heterosis.

It was observed that maximum heterosis over better parent was recorded for capsules/plant (54.9%) followed by seed yield/plant (39.6%) and effective branches/plant (18.7%). However, the highest standard heterosis was expressed by effective branches/plant (44.9%) followed by effective length of main raceme (34.8%), 100-seed weight (33.2%) and seed yield/plant (32.8%). Considerable heterosis in desired direction for these characters has been observed in earlier reports of Joshi *et al.* (2002) and Golakia *et al.* (2004). The data, further, showed that 8 of 9 heterotic crosses over better parent and 6 of 13 heterotic crosses over standard check were in desirable direction for seed yield/plant. The range of significant desirable heterosis for this character varied from 18.7 to 39.6% over better parent and 17.0 to 32.8% over standard check, suggesting that lines involved in these crosses might have different genetic systems which interacted and manifested heterosis for seed yield.

The extent of heterosis over better parent ranged from 16.1 to 54.9% for capsules/plant, 1.4 to 5.1% for oil content, 3.8 to 6.9% for shelling per cent, 8.9 to 16.3% for total length of main raceme, 8.9 to 16.3% for effective length of main raceme and 9.9 to 18.7% for effective branches/plant. These observations revealed that either gene controlling these traits were same in most of the lines or were so distributed that there has been substantial internal cancellation of gene effects or both. Since oil content, shelling per cent and 100-seed weight are important yield components, whose low heterotic response over better parent indicated that new diverse sources of genotypes have to be identified for the improvement of these characters.

Heterosis in negative direction for days to 50% flowering, days to maturity, nodes upto main raceme and plant height is desirable in the crop like castor to identify early hybrids suitable for rainfed production system. Heterosis for days to maturity in desirable direction (earliness) ranged from -1.8 to -7.6%. It suggested that there is a possibility of developing short duration hybrids. Mehta *et al.* (1991) also reported similar findings in castor. However, other earliness indicative traits, *viz.*, days to 50% flowering, nodes upto main raceme and plant height showed significant negative better parent heterosis in 9, 8 and 1 out of 20, 15 and 27 hybrids, respectively, clearly showing that more number of hybrids tended to express undesirable better parent heterosis than desirable one. Such tendency of hybrids in the present study suggested that most of the genes governing earliness might be due to undesirable gene action. Therefore, there is a need to investigate other sources of genes for earliness.

For exploitation of heterosis at commercial scale, its magnitude over standard check is very important. In the present study, the heterosis over standard check (GCH 6) was observed to the extent of 32.8% for seed yield/plant. Among the remaining traits, effective branches/plant (44.9%), effective length of main raceme (34.8%) and total length of main raceme (33.2%) also showed good amount of heterosis in desirable direction. Significant heterosis for seed yield/plant in castor has been reported by several workers (Lavanya and Chandramohan, 2003; Thakker *et al.*, 2005 and Lavanya *et al.*, 2006). It was observed that all the traits expressed significant standard heterosis in desirable direction. However, numbers of crosses showing significant standard heterosis in desirable direction were 6 for seed yield/plant, 18 for effective branches/plant, 21 for nodes upto main raceme and 14 for oil content.

The best hybrids sorted and listed out in Table 2 indicated that the magnitude of heterosis over better parent and standard check varied substantially from cross to cross and from character to character. This indicated the existence of potential heterosis in castor. The JP 65 x JI 309 was the best hybrid with respect to better parent heterosis (39.6%) and JP 88 x DCS 89 was superior according to standard heterosis (32.8%) for seed yield/plant. However, both these hybrids were failed to express the highest heterosis for other component traits. This indicated that the magnitude of heterosis over better parent and standard check varied from cross to cross for

the characters under consideration. This may be due to the presence of variable gene action in the parents used for the study. However, the best crosses involving SKP 72 female performed better for days to 50% flowering, nodes upto main raceme, capsules/plant, effective branches/plant, shelling per cent and oil content over better parent, whereas, pistillate line JP 82 in the best crosses showed good performance over standard check for earliness, short plant stature, lesser nodes upto main raceme and high oil content.

The best crosses involving male line JI 309 showed good heterotic performance over better parent for seed yield/plant, nodes upto to main raceme and days to 50% flowering. Whereas, over standard check, the crosses involving male line DCS 89 expressed superior performance for seed yield/plant and effective branches/plant. Five superior crosses for seed yield *per se*, their heterotic response to yield and its components over better parent and standard check (Table 2) indicated that all the hybrids manifested significant standard heterosis for seed yield, however, two hybrids, *viz.*, JP 88 x JI 274 and JP 65 x JI 309 expressed significant better parent heterosis. The hybrid, JP 88 x DCS 89 was the highest yielding cross combination on the basis of *per se* performance as well as standard heterosis. This cross also displayed significant standard heterosis in desirable direction for effective branches/plant (44.9%) and capsules/plant (12.5%). The cross between JP 65 and JI 309 exhibited the highest better parent heterosis for seed yield, though it was fifth on the basis of *per se* performance and standard heterosis. This cross had not shown desirable significant better parent heterosis for component characters. Thus, large extent of heterosis expressed by hybrids was evident for seed yield. However, there was no indication that component traits heterosis has contributed significantly toward the heterosis for seed yield, except effective branches/plant for standard heterosis. This indicated that heterosis for seed yield in these crosses could be due to unidirectional dominance and complementary action of majority of genes present in two parents favouring higher yield.

On the basis of *per se* performance, the hybrids JP 88 x DCS 89, JP 65 x DCS 89, JP 88 x PCS 124, JP 88 x JI 274 and JP 65 x JI 309 were promising over standard check. The identified promising hybrids need to be further tested extensively in different agroclimatic zones for their superiority and stability for seed yield before their recommendation for commercial cultivation.

Table 1 Analysis of variance over environments for twelve characters in castor

Source	d.f.	Days to 50% flowering	Days to maturity	Plant height	Nodes upto main raceme	Total length of main raceme	Effective length of main raceme	Capsules/ plant	Effective branches/ plant	100-seed weight	Shelling (%)	Oil content (%)	Seed yield/ plant
Replication/E	8	32.72*	33.94*	314.58*	5.50*	207.18*	208.56*	1465.41*	12.61*	0.35	20.29*	30.36*	5922.71*
Environments (E)	3	7521.62*	4872.42*	8224.93*	67.96*	2021.75*	1945.11*	3394.73*	181.57*	41.52*	110.02*	170.51*	101915.30*
Genotypes (G)	58	83.43*+	83.01*+	291.54*+	6.20*+	178.14*+	179.44*+	527.77*+	9.60*+	89.55*+	21.71*+	2.85*+	1812.46*+
Parents (P)	14	394.00*+ (64.20)	331.52*+ (119.38)	1364.4*+ (63.44)	29.67*+ (17.46)	703.56*+ (36.34)	716.87*+ (36.20)	2321.11*+ (47.35)	62.09*+ (8.60)	512.15*+ (32.13)	87.09*+ (62.52)	5.60*+ (49.24)	75558.37*+ (112.44)
Hybrids (H)	43	164.71*+ (60.13)	134.40* (113.82)	729.41*+ (62.58)	12.52*+ (16.67)	396.80* (44.59)	397.69* (44.42)	603.63*+ (66.70)	18.57*+ (7.95)	193.90*+ (30.67)	45.97*+ (64.82)	7.92* (49.85)	3953.00*+ (124.90)
P vs H	1	1918.43*+	4020.00*	255.50*	124.64*	4084.00*+	4085.37*+	33380.44*+	1.68	74.09*	582.62*	74.69*+	39564.88*
G x E	174	11.26*+	14.68*	31.58*+	0.70*	12.55*	12.20*	80.10*	1.63*	2.71*+	4.12*	0.53*+	628.87*
P x E	42	47.12*	50.44*	121.41*	2.62*	70.48*	66.69*	358.63*	5.15*	166.87*	10.95	2.04*	1750.38*
H x E	129	29.35*	40.07*	86.82*	1.79*	26.17	25.93	189.50*	4.69*	5.12*	12.69*	1.25	1940.90*
P vs H x E	3	3631*	124.23*	61.89	7.51*	70.74*	74.63*	767.28*	8.80*	16.69*	17.01	10.00*	1458.03
Error	464	4.97	4.81	35.13	0.95	22.44	23.02	108.39	0.88	1.00	9.01	0.63	741.53

* Significant at 5% level against error mean square
\+ Significant at 5% level against respective interaction mean square
Figures in parenthesis are mean values

Table 2 *Range of heterosis and five top hybrids selected for seed yield per se showing heterosis over better parent and standard check for twelve characters in castor (Pooled over four environments)*

Character	Heter-over	Range of heterosis (%)@	JP 88 x DCS 89	JP 65 x DCS 89	JP 88 x PCS 124	JP 88 x JI 274	JP 65 x JI 309
Mean seed yield/plant (g)	-	-	*172.83*	*157.83*	*156.75*	*155.00*	*152.25*
Days to 50% flowering	BP	-3.2 to -14.6	7.54**	2.88	-1.37	-4.35**	6.56**
	SC	-3.2 to -9.7	11.36**	8.52**	2.08	-3.03	13.07**
Days to maturity	BP	-1.8 to -7.6	1.53	-5.52**	-0.88	-5.04**	0.79
	SC	-1.6 to -5.0	3.19**	1.63*	0.74	-3.49**	7.94**
Plant height	BP	-6.6 to -6.6	6.00	19.97**	21.60**	9.48*	20.43**
	SC	-9.1 to -21.1	21.27**	3.17	2.64	-2.38	3.57
Nodes upto to main raceme	BP	-5.4 to -12.1	6.09**	-0.94	0.10	1.87	-1.32
	SC	-5.6 to -17.1	6.09**	0.29	-6.85**	-12.08**	0.10
Total length of main raceme	BP	8.9 to 16.3	2.58	15.51**	-7.93	-0.18	3.58
	SC	9.8 to 33.2	6.72	11.52**	-4.22	3.84	0.00
Effective length of main raceme	BP	*8.9 to 16.3*	*2.40*	*15.51***	*-7.93*	*-0.18*	*1.59*
	SC	11.7 to 34.8	7.77	12.82**	-3.11	5.05	-0.78
						-16.74**	
Capsules/plant	BP	16.1 to 54.9	0.55	18.71**	-7.98	-6.95	6.32
	SC	12.4 to 16.2	12.48*	11.78	3.10		-0.02
Effective branches/plant	BP	9.9 to 18.7	-8.78**	-23.05**	-11.54**	-5.59	-22.69**
	SC	*10.7 to 44.9*	44.88**	22.22**	25.27**	17.65**	12.85*
100-seed weight	BP	0.7 to 4.0	0.93*	-4.19**	-1.95	-6.08**	-10.36**
	SC	10.2 to 33.2	-7.03**	-2.38	-18.11**	-1.63	33.22**
Shelling (%)	BP	3.8 to 6.9	4.28	1.61	1.90	0.53	2.01
	SC	5.3 to 5.3	1.72	-0.89	-0.85	-2.18	-2.19
Oil content (%)	BP	1.4 to 4.1	0.71	0.31	0.27	2.11**	-0.37
	SC	1.9 to 4.5	0.59	0.19	0.75	0.18	-1.61*
Seed yield/plant	BP	18.7 to 39.6	10.08	0.53	12.63	21.41*	39.57**
	SC	17.0 to 32.8	32.83**	21.24*	20.37*	19.06*	16.98**

BP = Better parent; SC = Standard check
*, ** Significant at 5% and 1% level of significance, respectively
@ Significant desirable heterosis

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Particle gun mediated DNA delivery and transient expression of β-glucuronidase (*GUS*) gene in niger, *Guizotia abyssinica* L.

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Abstract

Genetic transformation of three seedling explants *viz.*, hypocotyls, cotyledonary leaves and primary leaves of four niger, *Guizotia abyssinica* L., genotypes *viz.*, JNC-6, KGN-2, Deomali and CTP-local was attempted. Transient expression of β-*GUS* gene was reported in all the three explants of the four niger genotypes. The transient expression was found to be genotype- as well as explant-dependent. The hypocotyls of the genotype Deomali recorded the maximum (55%) transient *GUS* expression.

Key words: Niger, seedling explants, particle gun, *GUS* expression

Introduction

Niger (*Guizotia abyssinica* L.) is an important oilseed crop of tropical and subtropical areas of the world. It contributes nearly 50% and 3% of Ethiopian and Indian oilseed production, respectively. Mostly grown in tribal areas in India, it is considered as "Lifeline of tribal agriculture and economy". It yields high quality edible oil with pleasant and nutty sweet taste. Its importance is well known in human nutrition as it contains high amount of the essential unsaturated fatty acid, linoleic acid (85%); high amount of cysteine, and has the ability to reduce blood cholesterol. The seed itself is edible with no anti-nutrients (Nagaraj and Patil, 2004). Further, it finds its uses in pharmacy, food industry, and in the manufacture of soap, paints and illuminants (Riley and Belayneh, 1989). In recent years, it has gained much economic importance in context of inadequate oilseed production and due to its high export potential on account of being free from pesticide residues. It has also been an important crop as it has the potentiality to give sustainable yield under rainfed situation.

Niger crop by virtue of its enormous variability to various characters of economic importance offers tremendous scope for improvement through heterosis breeding. But, being a minor oilseed crop, very little attention has been drawn towards its genetic improvement (Nagaraj and Patil, 2004). Conventional methods have not been very successful to develop efficient genotype. The difficulties hampering the breeding of niger are attributed to very small flowers congregated in the capitulum, highly heterozygous and heterogeneous nature of the crop, narrow genetic base and limited success of inter-specific crosses.

In this context, biotechnological tools can supplement the breeding of niger either by creating the genetic variation or by selecting the variants produced *in vitro*. Further, it can be useful in creating somatic hybrids. Procedures were developed for callus induction and plant regeneration from cotyledons (Sarvesh *et al.*, 1993), callus induction and organogenesis from zygotic embryos and androgenesis (Sarvesh *et al.*, 1994), whole plant regeneration from seedling explants (Nikam and Shitole, 1997) and for the maintenance of the genetic male-sterile line of niger *in vitro* (Sujatha, 1997). These studies have reported 16 to 93% shoot regeneration either through direct regeneration or via callus-mediated route.

Despite a number of reports on tissue culture aspects of niger, the studies on genetic transformation are too scanty (Murthy *et al.*, 2003). Realising the amenability of niger seedling explants to tissue culture with the exception of roots (Nikam and Shitole, 1993), the particle gun mediated gene transfer was considered as an appropriate method. During the past few years, this method has been employed to develop transgenics in a large number of plant species (Khurana and Khurana, 2000). This method has the merits of use of more simplified constructs, simplified transformation protocols and above all, species independent transfer of DNA into a variety of target tissues (Gray and Finer, 1993). Keeping in view the efficacy of this technique and the ease of developing whole plantlet *in vitro*, an attempt was made to standardize protocols for direct transformation of niger.

Material and methods

The present investigation on genetic transformation of three seedling explants (hypocotyls, cotyledonary leaves and primary leaves) of four niger genotypes (JNC-6, KGN-2, Deomali and CTP-local) was conducted in the Department of Genetics and Plant Breeding, College of

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Agriculture, ANGRAU, Hyderabad. Prior to genetic transformation, an experiment was conducted to determine suitable seedling explant and appropriate hormonal combination for regeneration using seedling explants of the genotype KGN-2. The results revealed that the root-induced calli failed to regenerate shoots. Regenerative incompetence of roots has also been reported earlier (Nikam and Shitole, 1993). Hence, the root explant was not considered for transformation studies.

Regeneration: Four niger cv. KGN-2, CTP-local, JNC-6, Deomali and a local variety were tested for their regenerative competence. Seeds were surface sterilized using 0.1% (w/v) mercuric chloride for 6 to 8 min followed by three rinses with sterile distilled water. Seeds were then inoculated on half strength MS basal medium with 1.5% sucrose and 0.8% agar (Himedia, Mumbai, India) in culture tubes (25 x 150 mm). The medium was adjusted to 5.7 ± 0.1 pH using 0.1N NaOH or HCl and autoclaved at 15 psi and 121°C. Three types of explants, hypocotyls, cotyledonary leaves and primary leaves were isolated from 7-to 9-days old *in vitro* raised seedlings. The explants were cut into 1.0 cm segments and placed in contact with the medium surface. The explants were cultured in 9.0 cm petri dishes containing 20/cm^3 medium. The media combinations tested were BA (0.5, 1.0 and 2.0 mg/dm^3), TDZ (0.5 mg/dm^3) + NAA (0.2 mg/dm^3) and BA (1.0 mg/dm^3) + NAA (0.2 mg/dm^3).

Bombardment: Seedling explants *viz.*, hypocotyls, cotyledonary leaves and primary leaves from 7 to 9-day-old *in vitro* raised seedlings were excised, cut into 1.0 cm segments and subjected to bombardment using particle inflow gun model *Gene Pro 2000 He*. All the explants were given pre- and post-osmoticum treatment for four hours. The osmoticum medium consisted of MS medium + 0.2 M mannitol + 0.2 M sorbitol adjusted to 5.7 0.1 pH and autoclaved.

The plasmid pCAMBIA1391Z used in this study contained the *GUS* gene driven by CaMV 35S promoter. The plasmid was cloned in *E. coli* (DH 5α) and isolated by alkaline lysis method. Purified DNA was suspended in sterile distilled water and the concentration was adjusted to 1-2 μg/μl for the coating of particles for bombardment.

Tungsten particles were used and prepared according to manufacturer's instruction. DNA coated micro-carriers were loaded onto the nozzle of bombarding device. The explants were placed in the center of 90mm petri-plates containing the osmoticum medium. The bombardment was accomplished at a pressure of 12 kg/cm^2 and the distance was adjusted to 15 cm. Localization of *gus* expression by histochemical staining was carried out using 5-bromo-4-chloro-3 indolyl β-D glucuronide (X-Gluc), as described by Jefferson *et al.* (1987). The tissue was subsequently cleared using 70% ethanol.

Experimental design and data collection: The experiment was completely randomized with three replications and each replication contained four petri dishes each with 12 to 15 explants for regeneration and 25 to 30 explants for bombardment. Observations were recorded after three weeks of culture on shoot induction from various seedling explants for regeneration. Data was recorded on the frequency of *GUS* gene expression within 16-20 hr of bombardment. Data was subjected to angular transformation and statistically analyzed (FCRD) at α= 0.05.

Results and discussion

Regneration: In the experiment designed for assessing the genotypic response for shoot regeneration, hypocotyl, cotyledonary leaf and primary leaf explants of four genotypes *viz.*, JNC-6, CTP-local, Deomali and a local variety were cultured on five selected medium supplemented with BA (0.5-2.0 mg/dm^3), TDZ (0.5 mg/dm^3) + NAA (0.2 mg/dm^3) and BA (1.0 mg/dm^3) + NAA (0.2 mg/dm^3). The results revealed that shoot regeneration frequency was influenced by genotype, explant, hormonal treatment as well as their interaction (Table 1). Over all the genotypes, shoot regeneration was the maximum from hypocotyl (49.5%) followed by primary leaves (40.9%) and cotyledons (39.3%) and the differences were statistically significant.

The maximum shoot regeneration frequency from hypocotyl (54.6%) and cotyledon (46.7%) was observed on 1.0 mg/dm^3 BA and from primary leaves (47.0%) on 1.0 mg/dm^3 BA + 0.2 mg/dm^3 NAA. Among the genotypes, JNC-6 performed best with 48.8% frequency, while CTP-local recorded with the least shoot regeneration frequency of 36.9%. The genotype JNC-6 recorded maximum shoot regeneration frequency (55.1%) on medium supplemented with BA 1.0 mg/dm^3 .

Among the media combinations, the media supplemented with and BA (1.0 mg/dm^3) + NAA (0.2 mg/dm^3) and BA (1.0 mg/dm^3) responded optimally with shoot regeneration frequency of 46.7% and 46.4%, respectively and had comparable effects. The medium supplemented with TDZ (0.5 mg/dm^3) + NAA (0.2 mg/dm^3) was least effective.

Shoot multiplication and rooting: Adventitious shoots were subcultured on medium supplemented with 0.5 mg/dm^3 BA or Kn. Both the media combinations promoted shoot elongation. The medium supplemented with BA was effective in increasing both the number of shoots/explant (6 to 8) and shoot elongation, while the medium with Kn had pronounced effect on shoot elongation Elongated shoots (>5 cm) were subcultured on to medium with 1.0 mg/dm^3 NAA for induction of roots. Within three to four days of culture on rooting media, all the shoots produced roots. Almost all the shoot cultures developed into whole plantlet within a week.

Transformation: The amenability of tissues for transformation was evidenced by the blue-green appearance of bombarded tissues. The transformability was found to be explant- as well as genotype- dependent (Table 2).

Among the three explants, the significantly higher frequency (50.5%) of transformation was noted from hypocotyls. Chen and Beversdorf (1994) reported the hypocotyls as a better target for transformation. Cotyledonary leaves recorded least (35.4%) frequency of transient *GUS* expression, while primary leaves had an intermediate (37.5%) response. The differential responses of the explants may be attributed to the differences in their physical characteristics that affect particle penetration or there may be differences in biochemical characteristics that affect the expression of the *GUS* gene or the activity of the *GUS* enzymes. Sato *et al.* (1993) reported similar differences in transformation of shoot tips and embryogenic suspension cultures of soybean. The *GUS* expression was uniform in the hypocotyl segments as compared to cotyledonary leaves and primary leaves (Fig.1.).

Table 1 **Effect of MS medium with different concentrations and combinations of hormones on shoot regeneration frequency (%) from three seedling explants of four genotypes of niger**

Hormonal treatments (mg/dm³)	JNC-6				Local				CTP-Local				Deomali				Mean			
	H	C	PL	Mean	H	C	PL	Mean	H	C	PL	Mean	H	C	PL	Mean	H	C	PL	Mean
0.5 BA	53.8	33.3	40.0	42.4	60.0	40.0	30.0	43.3	50.0	25.0	33.3	36.1	50.0	40.0	38.4	42.8	53.5	34.6	35.4	41.2
1.0 BA	60.0	62.5	42.9	55.1	58.3	63.6	50.0	57.3	50.0	27.3	25.0	34.1	50.0	33.3	33.3	38.9	54.6	46.7	37.8	46.4
2.0 BA	50.0	50.0	33.3	44.4	37.5	28.6	25.0	30.4	44.4	38.5	50.0	44.3	41.7	38.5	66.7	49.0	43.4	38.9	43.8	42.0
0.5 TDZ+ 0.2 NAA	50.0	41.7	37.5	43.1	50.0	33.4	66.7	50.0	33.3	25.0	28.6	29.0	50.0	33.3	28.6	37.3	45.8	33.3	40.3	39.8
1.0 BA + 0.2 NAA	56.5	60.0	60.0	58.8	70.0	50.0	33.3	51.1	37.5	28.6	57.1	41.0	36.4	33.3	37.5	35.7	50.1	42.9	47.0	46.7
Mean	54.1	49.5	42.7	48.8	55.2	43.1	41.0	46.4	43.1	28.9	38.8	36.9	45.7	35.7	40.9	40.8	49.5	39.3	40.9	43.2

H = Hypocotyl; C = Cotyledonary leaf; PL = Primary leaf
All values are in percentage. The percentage values were transformed into angular values prior to statistical analysis

	Genotype (G)	Treatment (T)	Explant (E)	G x T	G x E	T x E	G x T x E
SEm±	0.51	0.57	0.44	1.14	0.88	0.98	1.97
CD (P=0.05)	1.02	1.37	0.88	2.27	1.76	1.97	3.94

Table 2 **Transient *GUS* expression (%) of different seedling explants (hypocotyls, cotyledonary leaves and primary leaves) of four niger genotypes**

Explant/Genotype	KGN-2	JNC-6	CTP-local	Deomali	Mean
Hypocotyl	52.0	45.0	50.0	55.0	50.5
Cotyledonary leaf	40.0	33.3	35.0	33.3	35.4
Primary leaf	35.0	40.0	35.0	40.0	37.5
Mean	42.3	39.4	40.0	42.8	41.1

Percentage values were angular transformed and subjected to statistical analysis.

	Explant (E)	Genotype (G)	G x E
SEm±	0.87	0.75	1.5
CD (P=0.05)	1.79	1.55	3.09

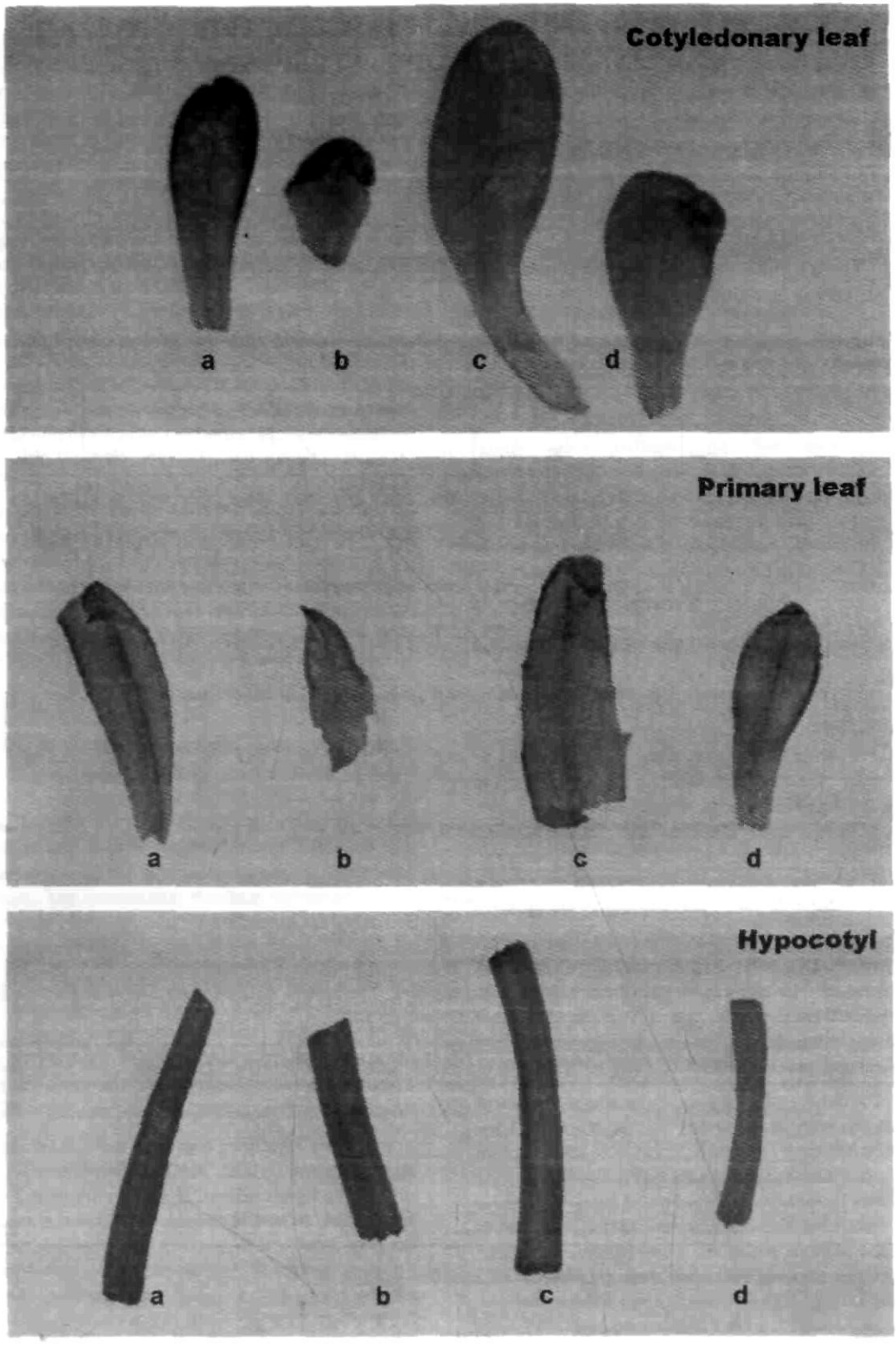

Fig. 1 *GUS* expression in different explants from different genotypes of niger

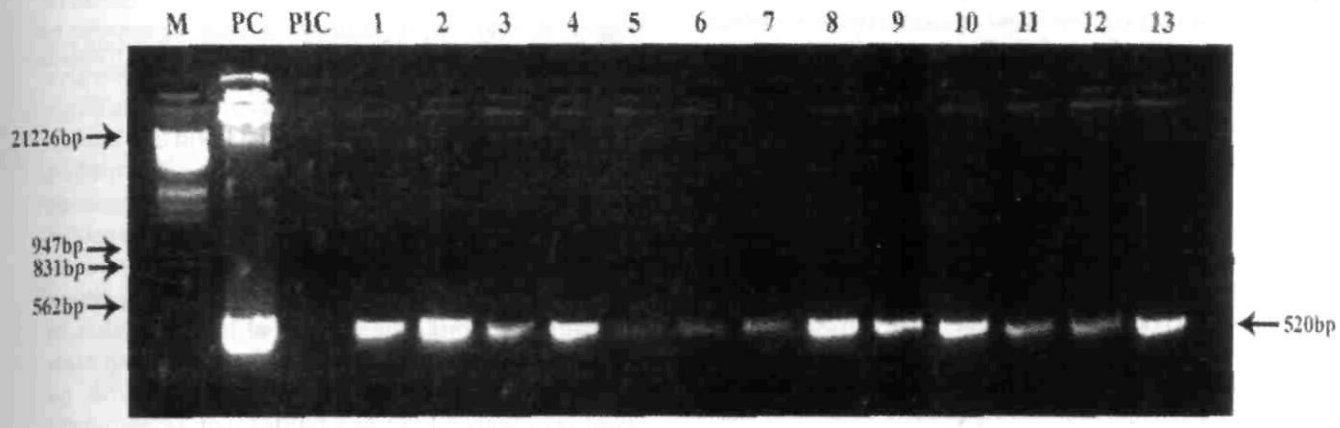

Fig. 2. PCR analysis of genomic DNA samples of putative transformants of niger in Eco RI Hind III double digest

PC-Plasmid DNA; PIC-Untransformed plant DNA as control; 1-13 putative transformants

Among the different genotypes, Deomali and KGN-2 responded with 42.8% and 42.3% of transformation frequency, respectively and had comparable effects, while the genotypes JNC-6 and CTP-local did not differ significantly and recorded the transformation frequency of 39.4% and 40.0%, respectively. These differences among the genotypes may be due to the differential levels of endogenous biochemical activities. These findings were in agreement with the reports of Moore *et al.* (1994) who reported that genotype and developmental stage of the zygotic cotyledons of soybean influenced the *GUS* expression following bombardment.

PCR Analysis: To confirm the presence of transgenes in the primary transformants, a number of transformants were tested by PCR amplification of genomic DNA using primers specific to *hpt* gene (Fig.2).

No amplified product was detected in the samples containing genomic DNA from an untransformed plant. PCR analysis of transfomants with *hpt* specific primers detected an amplified product of ~520 bp.

The present study indicated the successful transformation of seedling explants of niger using particle gun. The transformability of hypocotyls and cotyledons was established using *Agrobacterium tumefaciens* also (Murthy *et al.*, 2003).The study indicates the appearance of putative transformants. The bombarded tissues can be regenerated *in vitro* by utilizing the earlier devised media combination and can be analyzed for the stable transformation.

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Irrigation and sulphur management in summer groundnut, *Arachis hypogaea* L. under North Gujarat conditions

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Abstract

Among the irrigation schedules, the groundnut crop irrigated at 40 mm CPE (17 irrigations) brought significant improvement in growth (Plant height, spread and branches/plant) and yield attributes (filled pods/plant, 100 kernel weight and shelling percentage). The highest pod and haulm yield was achieved when crop irrigated at 40 mm CPE, accounted 8.9 and 19.9% pod and 8.9 and 16.5% haulm yield increase over 50 and 60 mm CPE. Sources of sulphur failed to exert their significant effect on yield (pod and haulm) of groundnut. Application of 40 kg S/ha showed its superiority on growth, yield attributes as well as pod and haulm yield over lower levels (0 and 20 kg S/ha) of sulphur. Significant positive interaction of irrigation and sulphur on pod yield of groundnut was noted with combination of irrigation scheduled at 40 mm CPE and application of sulphur @ 40 kg/ha.

Key words: Groundnut, CPE, sulphur, pod and haulm yield

Introduction

Gujarat is leading for area and production of groundnut in India, however the productivity is low because of low and erratic rains during monsoon. Dodiya (1985) visualized higher yield potential of summer groundnut grown in loamy sand soils of North Gujarat. Moreover, it can best be accommodated, as succeeding crop to potato and mustard, there is a scope for increase in area under summer groundnut with the availability of Narmada irrigation water in light texture soils under congenial environment of North Gujarat. Water management in light textured soils is crucial hence scheduling plays an important role in summer season. Nutritionally, sulphur is as important as phosphorus for oil seed crops. The available S status of the soils in Gujarat indicated average per cent deficiency of 44.3 % in North Gujarat, which was highest in the state (Patel *et al.*, 1986). Gypsum has been found either superior or equal to other S containing fertilizers in groundnut (Ghosh *et al.*, 2000). As the irrigation facilities are being increasing in semi-arid areas of Gujarat, scope of summer groundnut is bright under productive and profitable cropping system. Keeping the above considerations in view, the present investigation was undertaken to find out efficient irrigation schedules with requirement of sulphur for summer groundnut.

Materials and methods

The field experiment was conducted at Main Castor-Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar during summer 2003 and 2004 on the same site involving main plot treatments of three irrigation schedules i.e., 40, 50 and 60 mm CPE keeping 50 mm depth with the combination of two sources (elemental S and Gypsum) and four levels of S (0, 20, 40 and 60 kg/ha) as sub-plot treatments. The experiment was laid out in split plot design with four replications. The soil was loamy sand in texture having low in organic carbon (0.15%) and available sulphur (7 mg/kg) deficient in available nitrogen (163 kg/ha) and medium in available P_2O_5 (56.7 kg/ha) and K_2O (224 kg/ha). The mean maximum and minimum temperature ranged between 28.4°C to 41.5°C and 8.7 to 27.3°C, whereas evaporation ranged between 5.6 to 14.0 mm/day during the crop period. The mean soil moisture content (%) at field capacity was 6.54, 6.33, 6.24, 6.18 and 6.06. Permanent wilting point (%) was 3.46, 3.25, 3.10, 2.95 and 2.90 and bulk density (g/cc) was 1.63, 1.64, 1.65, 1.65 and 1.66 in 0-15, 15-30, 30-45, 45-60 and 60.75cm soil depth, respectively. The seeds of short duration bunch type variety GG-2 were sown on 7th and 14th February, during 2003 and 2004, respectively. The crop was fertilized with basal dose of 25 kg N/ha + 50 kg P_2O_5/ha and sulphur was applied 21 days prior to sowing during both the years.

Results and discussion

Among the irrigation schedules, I_1 (40 mm CPE) showed its superiority through bringing significant improvement in plant height, number of branches/plant and plant spread, number and weight of filled pods/plant, 100-kernel weight and shelling percentage. This might be due to greater cell elongation and improvement of turgidity with availability of adequate moisture. Scheduling of irrigation at longer interval (60 mm CPE) adversely affected the plant growth. Production of higher source under frequent irrigations created proportionately higher sink than that at long interval of irrigation. Irrigations given at 40 mm CPE (I_1) led

to the highest pod and haulm yield possibly due to improvement in growth and yield attributes.

Effect of sources of sulphur: Sources of sulphur failed to exert their significant influence on growth and yield attributes as well as on pod and haulm yield. This is attributed to equal response to both the sources on growth and yield parameters of groundnut. Similar findings have been reported by Bhaskar and Shivashankar (1993) emphasizing equal response of gypsum and sulphur treatments on groundnut.

Effect of sulphur levels: Application of sulphur @ 40 kg/ha significantly increased number of branches/plant, weight of filled pods/plant, 100-kernels weight over lower levels of sulphur. An increase in levels of sulphur up to 40 kg/ha brought significant improvement in pod and haulm yield. Application of 40 kg S/ha increased the pod yield to the tune of 19.9% over control (no sulphur). This might be due to multiple role of sulphur in metabolism as well as vegetative and reproductive development of the crop. This is attributed to increase in number of filled pods/plant, filled pod weight/plant, 100-kernel weight and shelling percentage by application of S @ 40 kg/ha over control. These results are in close conformity with the findings of Dodiya (1998) and Shahu *et al.* (2001).

Interaction effect of Irrigation and Sulphur: Interaction between irrigation and sulphur on weight of filled pods/plant and pod yield was found significant (Table 2). A successive increase in sulphur level under frequent irrigations (40 mm CPE, I_1) brought significant increase in weight of filled pods/plant. The highest weight of filled pods/plant (25.4 g) was observed with combination of I1S2 (40 mm CPE x 40 kg S/ha). Whereas the lowest weight of filled pods/plant (14.9 g) was noted under I_3S_0 (60 mm CPE x no sulphur). This might be due to efficient utilization of nutrients by the crop under adequate supply of sulphur with proper scheduling of irrigation.

The treatment combination I_1 S_2 (40 mm CPE x 40 kg S/ha) and I_1S_3 (40 mm CPE x 60 kg S/ha) found equally effective and achieved maximum pod yield. The pod yield increased under treatment combinations I_1S_2 and I_1S_3 was to the tune of 43.7 and 42.1% over I_3S_0 (60 mm CPE without S) combination. These results are in line with the findings of Tripathi and Patro (1996).

Table 1 Growth, yield attributes and yield as affected by irrigation schedules, sources and levels of sulphur (pooled)

Treatment	Plant height (cm)	Plant spread (cm)	Branches/ plant	Filled pods/ plant	Filled pod weight/ plant (g)	100-kernel weight (g)	Shelling percentage	Pod yield (kg/ha)	Haulm yield (kg/ha)
Irrigation schedules									
40 mm CPE	47	41	6	30	23	38	76	3784	6040
50 mm CPE	45	40	6	28	20	36	75	3475	5546
60 mm CPE	44	39	5	27	18	35	75	3156	5187
SEm±	0.3	0.4	0.05	0.2	0.2	0.2	0.08	76.3	94.5
CD (P=0.05)	1.0	1.2	0.16	0.6	0.5	0.5	0.2	234.3	290.0
Source									
Elemental S	45	40	6	28	21	36	75	3462	5598
Gypsum	45	40	6	28	21	36	75	3482	5583
SEm±	0.2	0.2	0.03	0.1	0.1	0.08	0.1	18.2	23.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Levels (kg/ha)									
Control	43	39	5	24	16	33	74	3085	5161
20	45	40	6	28	20	36	75	3414	5502
40	47	41	6	31	23	38	76	3699	5857
60	47	41	6	30	23	38	75	3688	5843
SEm±	0.6	0.1	0.04	1.0	0.3	0.1	0.2	25.8	33.8
CD (P=0.05)	NS	NS	0.12	4.3	1.5	0.5	0.4	89.1	117.1

Table 2 Interaction effect of irrigation schedules and sulphur on weight of filled pods/plant and pod yield of groundnut (pooled)

Irrigation	Levels of S (kg/ha)			
	0	20	40	60
Weight of filled pods/plant (g)				
40	18.2	23.3	25.4	25.2
50	16.1	20.3	22.4	22.4
60	14.9	17.3	20.1	20.4
SEm±	0.3			
CD (P=0.05)	0.9			
Pod yield (kg/ha)				
40	3339	3697	4073	4026
50	3082	3386	3717	3716
60	2834	3159	3308	3323
SEm±	44.6			
CD (P=0.05)	124.9			

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Response of sulphur nutrition on nutritional characteristics of oil and cake of sesame, *Sesamum indicum* L. varieties

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Abstract

A field trial was conducted to assess the effect of different sulphur levels (0, 10, 20 and 30 kg S/ha) on fatty acid profile and nutritional evaluation of two varieties of *Sesamum indicum* L. (T_4 and Shekhar). Laboratory analysis revealed a significant positive impact of increasing sulphur level on the oil content, fatty acid composition, protein, amino acid and total mineral content. Variable responses were observed in two varieties regarding fatty acid profile and nutritional contents. Oil content (50.15%) was found maximum in T_4. Maximum fatty acids such as oleic acid (41.65%), linoleic acid (37.00%), palmitic acid (9.26%) and stearic acid (94.36%) were recorded in T_4 variety. The maximum protein content (38.91%) and amino acid tryptophan (1.47%) was recorded in T4. Sulphur containing amino acids like methionine (2.23%), cysteine (1.66%) and cystine (1.43%) were obtained highest in cv. T_4.

Key words: *Sesame*, sulphur, protein, oil content, linoleic and methionine

Introduction

Sesame (*Sesamum indicum* L.) is an important edible oilseed crop of India and is a valuable nourishing food and flavouring agent. It is invariably dehulled for use as a food and on extraction, it produces oil. Its oil has a desirable fatty acid composition and excellent stability against oxidative rancidity. Sesame oil has relatively high percentage of unsaponifiable matter. Sesame oil also contains two minor constituents, sesamin and sesamolin togethers with sesamol which is present in traces. Sesamol is formed during hydrolysis of sesamolin. These chemical constituents possess antioxidant property.

After extraction of the oil from seed, cake or meal is obtained as a byproduct which is used as livestock feed. It is also utilized as ingredient of poultry feeds. Sesame meal is an important source of protein for human nutrition. Sesame seed can be eaten raw, and roasted. It can form a constituent of wide variety of foods and sweet meals, laddoo, tilwa, halwa, etc. It is also used to decorate bread, pastry, etc. It is widely used in the manufacture of soap, cosmetics, perfumes and pharmaceutical products in the preparation of scented hair oil and as a vehicle of fat soluble vitamins. Being importance of crop the present investigation was undertaken to evaluate nutritional quality of sesame oil and meal.

Material and methods

The present experiment was conducted in Randomized Block Design with three replications at the Student Instructional Farm of NDUA&T, Kumarganj, Faizabad, during the summer season of 2004-05. The treatment comprised four levels of sulphur in the form of gypsum i.e., control (0 kg/ha), 10 kg/ha, 20 kg/ha, 30 kg/ha and two varieties i.e., T_4 and Shekhar. Recommended dose of fertilizers i.e., N:P:K @ 30 : 15:15 kg/ha was applied. Nitrogen was applied in two splits i.e., half doses as basal application and the other half after first irrigation. Recommended agronomic practices and plant protection method were also adopted to grow a good and healthy crop.

Bold and healthy seeds obtained after harvesting were used for nutritional evaluation. The oil content in seeds was extracted with petroleum ether by "Soxhlet method" (AOAC, 1970), methyl esters was prepared and fatty acids were determined by gas liquid chromatography at the CDRI, Lucknow. The protein content of seed was determined as per Lowry *et al.* (1951) using crystalline bovine serum albumin protein as standard. The amino acid like tryptophan content was estimated by the method of Spies and Chamber. Sulphur containing amino acids like methionine content was analysed as described by Hort *et al.* (1949), while cysteine and cystine content in protein hydrolysate was determined by the procedure described by Leach (1966). The mineral content in the defatted cake was estimated by the method of Hort and Fisher (1971). The data recorded on above characters were subjected to statistical analysis as described by Panse and Sukhatme (1954).

Results and discussion

The sulphur fertilization and varieties brought about a significant response on oil content and nutritional components of the seeds (Table 1). The sulphur application @ 30 kg/ha, the T_4 variety gave the maximum oil content (49.23-51.43%) and it was significantly superior

over control and 10 kg S/ha but at par with 20 kg S/ha. The increasing trends in oil content may be due to the fact that sulphur nutrition created a favourable nutritional environment for production of metabolites responsible for oil biosynthesis inn plants. The results are in accordance to the report of Tashiro *et al.* (1990). The increasing trend was also observed in case of protein content and it was recorded maximum in T_4 variety (40.1%) at 30 kg S/ha. This may be due to the fact that sulphur besides being a structural component of protein is also directly involved in protein biosynthesis. The results are in conformity with the findings of Trivedi and Sharma (1997). With the increase in sulphur levels, T_4 variety showed significant increase in oleic acid (40.04-43.34%), linoleic acid (35.40-38.69%), palmitic acid (7.81-11.30%) and stearic acid (3.41-5.63%, respectively). The results are in conformity with that obtained by Bewley and Black (1978). This may be due to the fact that acetate available in seeds get converted into fatty acids having 18 carbon atoms in protoplast of oilseeds endosperm leading to increase inn oleic, linoleic, palmitic acid and stearic acid. The tryptophan content of sesame cake was noticed in the range from 1.06-2.03%. Maximum tryptophan was recorded in T_4 variety followed by Shekhar. The influence of sulphur fertilization and varieties led to a significant increase in the tryptophan content of the sesame cake. Maximum tryptophan content was obtained in cv. T_4 with application of 30 kg S/ha (Table 2). The increase in trypophan content of cake was probably due to increased protein synthesis with sulphur fertilizer and its negligible role in formation of aromatic (i.e., tryptophan) amino acid. This is in accordance to the results obtained by Abidi *et al.* (1991). The maximum methionine content (1.87-2.53%) was obtained in cv. T_4 by the application of 30 kg S/ha. This may probably due to the fact that methionine contains sulphur as an important constituent and helps in biosynthesis of amino acids (Miller, 1959). Moreover, sulphur is a component of essential vitamins and enzymes necessary for synthesis of methionine. The results are in agreement with the findings of Abidi *et al.* (1979). The cysteine and cystine content in cake varied from (1.19-2.08%) and (1.03-1.91%), respectively among different treatments. The highest cysteine and cystine content were recorded in cv. T_4 at 30 kg S/ha. These amino acids are important constituent of sulphur containing amino acids and adequate supply of sulphur to the sesame crop might have led to proper synthesis of sulphur containing amino acids. The findings of present investigation are in accordance to Badiger *et al.* (1986), who reported that cysteine and cystine in sesame were significantly increased at 10 and 20 ppm sulphur levels. The positive impact of sulphur levels was also witnessed in case of mineral content and highest mineral content i.e., (5.03%) was noticed in T_4 followed by Shekhar variety.

Acknowledgement: The authors are thankful to the Director, CDRI, Lucknow for providing GLC facilities for carrying out fatty acid analysis during the experiment.

Table 1 Influence of sulphur on oil content and fatty acid composition of sesame varieties

	Varieties	Oil content (%)	Fatty acids (%)			
			Oleic acid	*Linoleic acids*	*Palmitic acid*	*Stearic acid*
	V_1 (T_4)	50.15	41.65	37.00	9.26	4.36
	V_2 (Shekhar)	49.05	40.84	36.73	9.06	4.01
	CD (P=0.05)	0.23	0.81	0.27	NS	0.25
S level	S_0	48.77	39.69	35.19	7.78	3.30
	S_1	49.23	40.69	36.19	8.38	3.50
	S_2	49.80	41.74	37.24	9.43	4.52
	S_3	50.61	42.87	38.34	11.06	5.36
	CD (P=0.05)	0.35	1.19	0.38	1.07	0.35
Interaction	$V_1 S_0$	49.23	40.05	35.40	7.81	3.41
	$V_1 S_1$	49.73	41.07	36.42	8.03	3.72
	$V_1 S_2$	50.23	42.15	37.50	9.11	4.68
	$V_1 S_3$	51.43	43.34	38.69	11.30	5.63
	$V_2 S_0$	48.30	39.32	34.98	7.74	3.20
	$V_2 S_1$	48.73	40.30	35.96	8.72	3.41
	$V_2 S_2$	49.37	41.32	36.98	9.74	4.35
	$V_2 S_3$	49.80	42.40	38.98	10.82	5.09
	CD (P=0.05)	NS	NS	NS	NS	NS

Table 2 Response of sulphur application on amino acids and mineral content of sesame varieties

	Varieties	Protein (%)	Tryptophan (%)	Methionine (%)	Cysteine (%)	Cystine (%)	Total mineral (%)
	V_1 (T_4)	38.91	1.47	2.23	1.66	1.43	4.95
	V_2 (Shekhar)	36.77	1.43	1.80	1.42	1.39	4.82
	CD (P=0.05)	0.89	NS	0.10	0.06	NS	0.02
S level	S_0	37.00	1.02	1.67	1.11	1.01	4.81
	S_1	37.32	1.25	1.87	1.41	1.22	4.87
	S_2	38.03	1.53	2.07	1.67	1.44	4.92
	S_3	39.00	1.98	2.50	1.98	1.95	4.97
	CD (P=0.05)	0.42	0.11	0.15	0.09	0.09	0.03
Interaction	$V_1 S_0$	38.03	1.06	1.87	1.19	1.03	4.87
	$V_1 S_1$	38.37	1.47	2.17	1.51	1.32	4.93
	$V_1 S_2$	39.13	1.59	2.37	1.86	1.47	4.98
	$V_1 S_3$	40.10	2.03	2.53	2.08	1.91	5.03
	$V_2 S_0$	35.97	0.99	1.47	1.03	1.00	4.75
	$V_2 S_1$	36.27	1.36	1.52	1.30	1.13	4.81
	$V_2 S_2$	36.97	1.59	1.76	1.49	1.41	4.85
	$V_2 S_3$	37.90	1.93	2.46	1.87	1.98	4.90
	CD (P=0.05)	NS	NS	NS	NS	NS	NS

S_0, S_1, S_2 and S_3 = 0, 10, 20 and 30 kg/ha

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Investigation on sowing time, plant density and nutrient requirements of hybrid castor, *Ricinus communis* L. for the non-traditional area of Punjab

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Abstract

Investigations carried out to work out the agronomy of castor for the non-traditional area of Punjab showed that sowing castor on 28th April produced significantly higher bean and oil yield compared with 28th May sowing. The crop sown on 30th July responded to the application of nutrients upto 60 kg N and 40 kg P_2O_5/ha, though the bean yield with 75 kg N/ha was 4.8% higher compared to 60 kg N/ha. The optimum spacing was found to be 90 cm x 75 cm for end July sowing, and 100 cm x 60 cm in case of end April sowing.

Key words: Castor, nutrients, plant density, sowing time

Introduction

Castor (*Ricinus communis* L.) occupies a place of pride in the dryland agriculture owing to its drought hardiness, quick growth, ability to adjust to edaphic, climatic and managerial factors and low input requirements. Oil from castor is among the most versatile products with varied industrial uses. The demand for castor oil in Punjab is escalating where large number of industrial units are located. While the country is spending million of rupees on importing edible oils to meet domestic requirements, it is the crop that fetches foreign exchange. This factor has caught the attention of farmers of the Punjab state. Moreover, increasing pressure on the natural resources *viz*., over exploitation of groundwater, excessive nutrient mining, increasing use of pesticides etc., leading to increasing cost of cultivation and decreasing profits from prevailing cropping systems have also compelled farmers of the state to look for alternative crops. Agroclimatic conditions of Punjab are quite suitable for castor cultivation and in the south-western districts and Shivalik foot hills, it can prove to be a profitable crop. At present, cultivation package for castor is not available in the state. Therefore, an investigation was carried out to work out the agronomic requirements of castor cultivation.

Materials and methods

Three independent field experiments were conducted at the Punjab Agricultural University, Ludhiana (30° 56', 75° 52'E, 247 m above msl) during 2003-05 to find out optimum sowing time, desired plant population and nutrient requirements of castor. The first experiment conducted in 2003-04 comprised nine treatment combinations of nitrogen and phosphorus. The treatments replicated four times were tested in a Split-Plot Design with three doses of nitrogen (60, 75 and 90 kg/ha) in the main plots and three doses of phosphorus (40, 50 and 60 kg P_2O_5/ha) in the sub-plots. A spacing of 90 cm between rows and 75 cm between plants within row was maintained.

In the second experiment conducted in 2003-2004, five spacing treatments (90 cm x 45 cm, 90 cm x 60 cm, 90 cm x 75 cm, 90 cm x 90 cm and 120 cm x 60 cm) were evaluated in a RBD with three replications. Nutrients were applied as 75 kg N/ha and 50 kg P_2O_5/ha uniformly in all the treatments.

For both the experiments, GCH 4 hybrid was sown on 30th July 2003 in a gross plot size of 9.0 m x 4.5 m. The loamy sand soil of the experimental site tested neutral in reaction (pH 7.7), low in organic carbon (0.24%) and medium in available phosphorus (17.0 kg/ha). Half dose of nitrogen as urea and full dose of phosphorus as single superphosphate were drilled at sowing as per treatments, whereas the remaining half dose of nitrogen as urea as per treatments was top dressed at 40 days after sowing (DAS). In both the experiments, three picks were made at 110, 150 and 195 days after sowing.

The experiment conducted in 2004-05 consisted of two sowing dates (28 April and 28 May) in the main plots and six spacings (combinations of three inter row spacings of 75, 100 and 125 cm and two intra row spacings of 45 and 60 cm) in the sub-plots, replicated thrice in a split-plot design. Hybrid GCH 4 was sown as per treatments on loamy sand soil. Basal dose of 37.5 kg nitrogen as urea and 50 kg P_2O_5/ha as single superphosphate was drilled at sowing. Another dose of 37.5 kg N/ha as urea was applied 45 days after sowing. The crop was harvested twice at 135 and 235 DAS in case of 28 April sowing and 105 and 205 DAS in case of 28th May sowing. In all the experiments, the crop was sown after pre-sowing irrigation to ensure uniform germination. In 2004-05, one post sowing irrigation was also applied. The crop received

rainfall of 393 mm in 26 effective rainy days and 427 mm in 20 effective rainy days during the growth period in 2003-04 and 2004-05, respectively.

Results and discussion

Effect of nutrients: Different ancillary characters, bean yield, oil content and oil yield of castor were not significantly influenced by varied doses of nitrogen and phosphorus (Table 1). However, application of 75 kg N/ha resulted in 4.8% higher bean yield and also oil yield over 60 kg N/ha (15.9 q/ha). The bean yield decreased with increasing doses of phosphorus and application of 40 kg P_2O_5/ha was found optimum (Table 1). Patel *et al.* (1991) reported highest seed yield of GAUCH 1 with 75 kg N/ha on loamy sand soils testing low in organic carbon and available nitrogen. Mathukia and Modhwadia (1995) also reported that seed yield of castor with 50 kg N/ha was at par with 75 and 100 kg N/ha. Raghavaiah and Sudhakara Babu (2000) also reported increase in seed yield of GCH 4 upto 50 kg N/ha with no additional advantage with 75 and 100 kg N/ha. Castor roots have the ability to utilize bound form of phosphorus (Patel, 1985). Paida and Parmar (1980) and Mathukia and Modhwadia (1995) also did not observe any influence of phosphorus application varying from 0 to 90/100 kg P_2O_5/ha on seed yield of hybrid castor.

Effect of spacing: In 2003-04, varied plant populations of GCH 4 obtained by different inter-row and intra-row spacings did not have discernible influence on ancillary characters, bean yield and oil content of castor (Table 2). The highest bean yield (15.2 q/ha) obtained with 90 cm x 75 cm spacing (14815 plants/ha) was 23.8% more than 90 cm x 45 cm and 120 cm x 60 cm spacings. The highest oil yield was also recorded with 90 cm x 75 cm spacing. Similarly bean yield with 90 cm x 75 cm was 6.9% and 13.8% higher than that registered with 90 cm x 60 cm and 90 cm x 90 cm spacings, respectively. Closer spacing of 90 cm x 45 cm (24691 plants/ha) and wider spacing of 120 cm x 60 cm (13889 plants/ha) resulted in lower bean yield (12.3 q/ha).

However, in 2004-05, bean yield of GCH 4 was significantly influenced by different inter-row and intra-row spacings (Table 3). Row spacing of 100 cm with plant spacing 60 cm (16667 plants/ha) resulted in bean yield comparable with 75 cm x 60 cm (22222 plants/ha) and 125 cm x 45 cm (17778 plants/ha), and these significantly out yielded 75 cm x 45 cm (29630 plants/ha) and 125 cm x 60 cm (13333 plants/ha) spacings. The study, thus, highlights that both plant density and crop geometry influence crop growth and yield, probably through their effect on canopy structure and leaf area development which ultimately decide the solar radiation interception and utilization of other growth resources. Several workers have reported higher bean/seed yield with inter row spacing of 90 cm and intra row spacing of 60 cm (Sarma 1985; Thadoda 1993; Vala *et al.*, 2000). Thadoda *et al.* (1996) also reported lower seed yield with wider row spacing (120 cm x 45 cm and 120 cm x 60 cm) as compared to 90 cm x 60 cm spacing.

Effect of sowing dates: Castor bean yield (25.7 q/ha) and oil yield (13.3 q/ha) with 28 April sowing was significantly higher than 28 May sowing (Table 3). The increase in yield with early seeding mainly accrued from significantly higher number of capsules/plant and 100-seed weight compared to delayed sowing. Singh and Singh (1988) from Bawal, Harayana and Subba Reddy *et al.* (1999) from Andhra Pradesh also observed reduction in seed yield with delayed sowing in a particular season.

Effect of sowing dates and spacings: Interaction of sowing dates with spacings was significant for bean yield (Table 3). In case of 28 April sowing, bean yield with row spacing of 100 cm and plant spacing of 45 or 60 cm (also with 75 cm x 60 cm spacing) remaining comparable gave significantly higher yield than 75 cm x 45 cm and 125 cm x 60 cm spacings. The highest bean yield registered with 100 cm x 60 cm (28.7 q/ha) was 37.4% greater than that harvested from 125 cm x 60 cm (20.9 q/ha). However, in case of 28 May sowing, bean yield with different spacings was at par with each other.

Table 1 Effect of nitrogen and phosphorus on the yield components, bean yield and oil content of castor

Treatment		Plant height upto primary spike (cm)	No. of primary branches/plant	No. of capsules/ main spike	100-seed weight (g)	Bean yield (q/ha)	Oil content (%)	Oil yield (q/ha)
Doses of nitrogen (kg/ha)	60	134	3.3	49	25.1	15.9	52.1	8.3
	75	131	3.5	44	24.8	16.7	52.1	8.7
	90	139	3.6	47	24.7	15.4	52.4	8.1
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Doses of phosphorus (kg P_2O_5/ha)	*40*	*136*	3.7	*46*	24.7	17.4	51.9	9.0
	50	134	3.2	45	25.0	15.7	52.4	8.2
	60	135	3.5	*49*	*25.0*	*14.9*	*52.3*	*7.8*
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 2 Effect of spacing on growth, yield attributes, bean yield and oil content of castor

Spacing (cm)		Plant population ('000/ha)	Branches/ plant	Plant height upto primary spike (cm)	No. of capsules/ plant	100-seed weight (g)	Bean yield (q/ha)	Oil content (%)	Oil yield (q/ha)
Inter-row	Intra-row								
90	45	24.69	3.1	136	68	25.4	12.3	50.9	6.3
90	60	18.52	3.3	136	69	26.0	14.2	51.0	7.3
90	75	14.82	3.6	135	75	26.0	15.2	51.3	7.8
120	90	12.35	3.6	130	66	26.2	13.4	51.8	6.9
CD (P=0.05)	60	13.89	NS	138	61	26.6	12.3	52.2	6.4
				NS	NS	NS	NS	NS	NS

Table 3 Effect of varied spacings on the bean and oil yield (q/ha) of castor sown on two dates

Sowing dates		Spacing (cm)						
		75 x 45	75 x 60	100 x 45	100 x 60	125 x 45	125 x 60	Mean
Bean yield (q/ha)	28th April	23.3	27.4	27.0	28.7	27.0	20.9	25.7
	28th May	13.4	14.9	12.2	13.3	13.5	13.3	13.4
	Mean	18.4	21.1	19.6	21.0	20.3	17.1	
Oil yield (q/ha)	28th April	11.8	14.0	14.0	14.5	14.3	11.0	13.3
	28th May	6.7	7.5	6.2	6.7	6.7	6.7	6.8
	Mean	9.2	10.8	10.1	10.6	10.5	8.8	
			Seed yield (q/ha)		**Oil yield (q/ha)**			
CD (P=0.05)	Sowing dates		2.71		1.27			
	Spacing		2.01		NS			
	Sowing dates x spacing		3.73		NS			

The study thus reveals that under agroclimatic conditions of Ludhiana, Punjab, hybrid castor sown on 28th April produced higher seed yield. The optimum spacing was found to be 90 cm x 75 cm or 100 cm x 45 cm. For optimum yield, the crop required 60 kg N and 40 kg P_2O_5/ha.

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Simulated defoliation during different crop growth stages to assess insect damage and yield losses in Spanish groundnut, *Arachis hypogaea* L.

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Abstract

Field trials were conducted during three post rainy seasons from 1999 to investigate the impact of insect simulated artificial defoliation on Spanish groundnut variety cv-GG 2. Four different defoliation levels were tested i.e., no defoliation (treated it as control), 10, 25, 50 and 75% at different crop growth stages such as vegetative, pegging, pod-filling and their combinations such as vegetative + pegging, vegetative + pod filling and pegging + pod filling. Pooled analysis (three years) showed that irrespective of the growth stages, leaf area growth rate increased with increase in percentage defoliation, up to 50% and it was minimum at 75% defoliation. Pod yield loss increased with increase in percentage defoliations during all the stages and their combinations. At 10% defoliation during vegetative stage the reduction in pod yield was 19.3% over control and highest (64.2 %) was observed at 75% defoliation during pegging + pod filling stage. The reduction of pod yield over control increased with higher intensity of defoliation and during advanced stages of the crop. Therefore, defoliation at any stage of the crop could results in significant loss in yield.

Key words: *Arachis hypogaea*, defoliation, compensation, yield loss

Introduction

Among the biotic stresses, insect pests and diseases cause direct damage to foliage and loss of photosynthetic area resulting in low productivity. Insect pests such as groundnut leaf miner. *Aproaerema modicella* Dev., tobacco caterpillar, *Spodoptera litura* (F.); gram pod borer, *Helicoverpa armigera* (Hubner) and red hairy caterpillars (RHCs), *Amsacta albistriga* Walk., *A. moorei* Butler and *Spilosoma obliqua* (Walk.) mines or devour the leaves and feed. The total leaf area is closely related with photosynthesis and ultimately partitioning of the photosynthates (Nautiyal *et al.*, 1999), and may reduce pod yield considerably (Panchabhavi *et al.*, 1986). The loss in yield because of defoliation dependent on the growth stage of the crop and plant recovery and compensation through production of new foliage (Taylor, 1972). Artificial defoliation of groundnut cultivar Dh 8 showed reduction in pod yield and 100-kernel weight (Panchabhavi *et al.*, 1986).

To simulate the damage caused by defoliating insects is a difficult task because artificial defoliation using scissors to cut the foliage may not be the same as actual feeding pattern of insect (Rice *et al.*, 1982). Under this situation, to estimate the loss due to one insect, the study should necessarily exclude other insects form the plots, which is impossible in open field conditions, unless the whole experiment is done under controlled condition with artificial inoculation/release of the required number of the insects. In spite of the difficulty of exactly simulating natural defoliation by the insect, the leaf cutting is considered a useful method to understand possible loss because of defoliation (Oyediran and Heinrichs, 2002). Insect pest damage input is important aspect of crop simulation modeling and requires information on yield loss caused because of insect pests damage (Boote and Jones, 1998).

Though, Greene and Gorbet (1973); Enyi (1975); Sharma and Shrimali (1981), Santos and Sutton (1982 and 1983) and Panchabhavi *et al.* (1986) studied the effect of artificial defoliation on the pod yield of groundnut, limited information is available on the response of groundnut cultivars to various levels of insect-simulated-artificial-defoliation during different growth stages individually and in combination and their effect on the pod yield. Present investigation was aimed to study the response of local groundnut cultivar to various levels of insect simulated defoliation during different stages of crop growth.

Materials and methods

Field trials were conducted at the National Research Center for Groundnut, Junagadh during the summer (February to June) seasons of 1999, 2000, and 2004. Experiments were conducted in semi-arid type of climate with temperatures ranging from 20°C to 40°C, average RH of 50 % and rainfall ranging from 550 to 850 mm. The experiment was laid out in shallow black soils which are calcareous in nature in a Completely Randomized Block Design (CRBD). A local cultivar GG 2 (*Arachis hypogaea* ssp. fastigiata) was selected for the study, and crop was sown in a plot size of 3 x 2m with a seed to seed distance

10 cm and row-to-row to 45 cm. All the recommended cultural practices were followed, nitrogen (N) and phosphorus (P) was given in the form of ammonium sulphate and single superphosphate @ 125 and 312 kg/ha respectively. A healthy crop was maintained by the need based application of monocrotophos 0.04%.

Insect simulated defoliation was performed manually by plucking the leaflets of the compound leaf and the petiole was left intact. Four levels of defoliations i.e., 10, 25, 50 and 75% were carried out at vegetative, pegging and pod-filling phases. The defoliation was also performed in combination of various growth stages such as vegetative + pegging, pegging + pod-filling and vegetative + pod-filling. All the treatments were replicated thrice. A control set was maintained in each replicate in which defoliation was not performed. Defoliation was planned keeping in view the solar radiation utilization at the different canopy levels i.e., 60% of the upper canopy level and 40% of the lower canopy and accordingly leaflets were removed manually. Total leaf area i.e. the intact leaf area developed after defoliation was monitored at 10 days interval. The total leaf area was calculated following the standard (25.91cm^2) leaf area of same cultivar (Nautiyal *et al.*, 1995), multiplied by the total number of leaves in the canopy. The increase in leaf area growth rate was compared to the control plots at 10 days interval and the excessive leaves were defoliated to maintain the specific levels. The increase in the leaf area growth rate compared to the previous stage was recorded. Crop was harvested at maturity and pod yield from each plot was recorded. The yield reduction with respect to the yield of control plots was calculated. The data on per cent increase in leaf area growth rate was analyzed for individual years and pooled over for 3 years following MSTAT statistical package.

Results and discussion

Foliage compensation during different growth stages: Removal of the leaves in various quantities during different growth stages i.e., vegetative, pegging and pod-filling showed increase in per cent leaf area growth rate compared to previous stage (Table 1). The groundnut plant responded differently with increase in per cent defoliation during different growth stages to the per cent increase in leaf area growth rate. During vegetative, pegging and pod filling stages the per cent increase in leaf area growth rate was increasing with increase in % defoliation up to 50% and at 75% it was minimum compared to control.

Foliage compensation during different combinations of growth stages: The per cent increase in leaf area growth rate was increased from 10% to 50% defoliation, and reached maximum at 50% defoliation during different combinations of growth stages such as vegetative + pegging, vegetative + pod filling and pegging + pod filling stages. While it was minimum at 75% defoliation compared to the control and other treatments during all combinations of growth stages.

It was difficult to simulate the defoliation studies to assess the damage caused by the insect pests because plant behaves differentially in its various phenological phases of the growth to insect pest damage and simulated defoliation either by the removal of leaf manually or scissors cut (Rice *et al.*, 1982). However, results of the present study could help in assessing the yield losses because of the defoliators, that damage the foliage during different growth stages of the groundnut.

Results of the pooled data indicated pod yield was significantly affected by artificial defoliation during different growth stages and in their combinations. The pod yield was maximum in control where groundnut plants were not defoliated at all. Similarly, Panchabhavi *et al.* (1986) reported that yield was highest without defoliation and lowest with 100% defoliation of 60-day-old plants. The percent loss in pod yield ranged from 19.3 to 36.4 during vegetative stage, during pegging it was from 25.2 to 41.2, during pod filling it was from 18.9 to 52.5, during vegetative + pegging the yield loss ranged from 21.4 to 61.4, during vegetative + pod filling it was from 26.3 to 62.6 and during pegging + pod filling the loss ranged from 22.5 to 64.2 at 10 and 75 % defoliation respectively compared to control (Table 2).

There was no significant difference in leaf area growth rate because of simulated defoliation during vegetative stage comparative to the other stages of the crop. Suggesting that if the injury occurs in the earlier stage of the plant the more rapid would be the plant to compensate the leaf area by forming new leaves and thus increased leaf area growth rate. Results showed that even at 10% defoliation at vegetative stages there was a pod loss of 19%. Thus removal of source (leaf) even at the vegetative stage has a significant bearing on the final yield reduction and it is presumed that if the 10% of the foliage is damaged by the insect pests pod yield is reduced significantly. Similarly, Panchabavi *et al.* (1986) reported pod loss of 8.9% and 7.1% when defoliation was done at 25% during 30 and 45 days after germination. Whereas, Santos and Sutton (1982) observed that defoliation of Virginia type of groundnut to early pod formation (10 weeks from sowing) caused no reduction in seed yield but in later treatments there were yield reductions of up to 40%.

While during pegging and pod-filling stages leaf area growth rate was least i.e., 61.2% and 164% respectively, at 75% defoliation compared to control which has higher foliage (190.1% at pegging; 320.1% at pod filling stage) where no defoliation occurred indicating that plant diverted energy to sink development instead to foliage compensation during these stages. There was more pod yield loss during combination of stages such as vegetative + pegging, vegetative + pod filling and pegging + pod filling indicating that plant diverted energy to sink

development instead to foliage compensation during these stages. This was in confirmation with Nautiyal *et al.* (1999) who reported the translocation was more effective at the pegging and pod-filling stages. Photosynthetic rate increased from vegetative to pegging phase, and was highest during pod development, however, during pod-filling phase photosynthetic rate was decreased. Partitioning of photosynthates to pods is the most important physiological factor in yield formation, besides pod number and duration of the pod filling. Maximum photosynthetic rate during pod formation phase showed that reproductive sink and its relative strength have an innate effect on photosynthesis (Ravindra *et al.*, 1995). In the present study the pod loss increased with increase in level of defoliation during different growth stages. Similarly, Bhattacharjee and Ghude (1985) reported progressive decrease in soybean yield as percentage defoliation increased at the bloom or post-bloom stages, whether the defoliation was natural or artificial.

Highest pod yield loss was recorded at 75% defoliation in groundnut during all the stages and their combinations as earlier reported by Greene and Gorbet (1973) and Enyi (1975). In the present study the pod loss increased with increase in level of defoliation during advanced growth stages. The present study indicated that pegging and pod filling are the critical periods of groundnut when the crop must be protected from defoliators for increasing the yields.

Table 1 Per cent increase in leaf area growth rate during different growth stages (Pooled mean of three years)

Defoliation (%)	Vegetative	Pegging	Pod filling	Vegetative + Pegging	Vegetative + pod filling	Pegging + pod filling
10	147.4	52.6	456.3	260.7	645.4	201.1
25	247.6	109.3	509.3	361.1	776.8	330.7
50	279.7	144.2	655.4	396.2	877.6	499.4
75	169.3	61.2	164.0	178.4	281.4	202.2
Control	229.9	190.1	320.1	373.1	520.5	575.9
SEm±	49.3	14.2	122.5	36.7	43.8	53.9
CD (P=0.05)	NS	41.1	354.0	109.2	126.5	155.9

Table 2 Reduction in groundnut pod yield (kg/ha) because of different intensity of artificial defoliation at different growth stages (Pooled mean of three years)

Defoliation (%)	Vegetative	Pegging	Pod filling	Vegetative + Pegging	Vegetative + pod filling	Pegging + pod filling	Mean
10	19.3	25.2	18.9	21.4	26.3	22.5	22.3
25	25.6	22.7	33.9	22.0	24.7	27.6	26.1
50	28.5	32.6	39.5	34.2	29.1	47.5	35.2
75	36.4	41.2	52.5	61.4	62.6	64.2	53.1
Mean	27.5	30.4	36.2	34.7	35.6	40.5	

	SEm±	CD (P=0.05)
Defoliation (D)	1.65	4.69
Stage (S)	2.02	5.75
Interaction (D x S)	4.03	11.49

Mean yield in control: 2623.5 kg/ha

No detailed study was made so far in groundnut for the compensation mechanism involved because of defoliation, however, the possible reasons for the compensation for defoliation could be that the partial defoliation may trigger increase photosynthesis in the remaining leaves and allow an improved supply of cytokinines to the remaining leaves by removal of sinks and leads to an increased carboxilation (Wareing *et al.*, 1968; Meidner, 1970; Daley

and Mcneil, 1987). Boote *et al.* (1980) reported that in the groundnut cv. early bunch and cv. Florunner the upper 42% of the canopy leaf area intercepted 74% of the light and fixed 63% of the total CO_2 taken up by intact canopies. Removal of 25% of leaf area reduced CO_2 uptake by 30% and canopy photosynthesis carbon exchange rate by 35%.

These results suggested that early control of insect pests could result in yield compensation that yield losses would be minimal by pod-filling stage. For development of IPM strategies for the groundnut farmers, the compensation of foliage in groundnut to defoliation because of insects or diseases must be given due consideration. These results are useful for determining the economic threshold levels (ETL) during different growth stages and the development of a pest management simulation model. Based on the present results, it is evident that even at 10 % defoliation leads to significant yield loss. Therefore, in order to harvest maximum yields the management tactics should be initiated even before 10 % defoliation.

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Relative preference of selected groundnut, *Arachis hypogaea* Linn. varieties to the groundnut bruchid, *Caryedon serratus*

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Abstract

Eight groundnut varieties *viz.*, JL 24, Kadiri 3, ICGS 44, Smruti (OG 52-1), GG 2, GG 11, TMV 2, and AK 12-24 were evaluated for their resistance to *C. serratus* under laboratory conditions. Studies on the ovipositional preference of *C. serratus* indicated the lowest preference for egg laying in Kadiri 3 and GG 2 varieties, while the varieties AK 12-24, TMV 2, and JL 24 were most preferred for oviposition by adults. Developmental preference of *C. serratus* was evaluated on the basis of larval duration, number of pupae and adults developed. Significant differences were found between the tested groundnut varieties in terms of grub developmental period, number of grubs that transformed into pupae and also adult emergence. On the basis of these parameters Kadiri 3 was found to be least preferred, while AK 12-24 and JL 24 were most preferred varieties.

Key words: Groundnut, bruchid, growth index biology

Introduction

Groundnut, *Arachis hypogaea* (Linn.),is a major oilseed crop of India. About 90% of total area and production is in the States of Gujarat, Andhra Pradesh, Maharastra, Tamil Nadu, Karnataka and Orissa. The crop is grown in an area of 6.74 m. ha and contributes 7.99 m. tonnes to the oilseed basket (Anonymous, 2007). It contains 44 to 50% oil and 22 to 30% protein on a dry seed basis and is a rich source of minerals like phosphorus, calcium, magnesium and potassium and vitamins such as E, K and B groups (Savage and Keenan, 1994). It is estimated that the post-harvest loss of oilseeds in India ranges between 10 to 25% of total oilseed production (Azeemoddin, 1993). Farmers, seed agencies and other storage organizations use to store more than 65% of their groundnut produce for consumption, seed and oil extraction purposes for more than 9 months. Efficient handling of post-harvest operations can minimize the losses between production and consumption. Groundnut pods harvested in the field pass through various stages to reach the ultimate consumers and are subjected to appreciable losses during storage. These losses are due to abiotic factors such as temperature and humidity as well as biotic factors *viz.*, insects, pathogens, rodents, mites and birds. Over one hundred species of insect pests have been recorded on stored groundnut (Redlinger and Davis, 1982). Among the major insect pests attacking groundnut in storage, groundnut seed beetle, *Caryedon* serratus (Olivier) is a very noxious one which inflicts colossal loss to pods as well as kernels (Dick, 1987 and Kapadia, 1994).

Considering the hazards of chemical pesticides in storage, now-a-days, due emphasis is being given to adopt suitable and effective non-chemical measures for mitigating the insect pest problems during storage. Host plant resistance mechanism in insect management has assumed greater significance in the present contest. Taking the above aspects into consideration, the present investigation was undertaken with an objective of evaluating the relative susceptibility/resistance of some popular groundnut varieties against *C. serratus*.

Materials and methods

Studies on relative resistance and susceptibility of eight groundnut varieties to C. serratus were carried out under laboratory conditions during January to April, 2006. Pods of eight groundnut varieties *viz.*, JL 24, Kadiri 3, ICGS 44, Smruti (OG 52-1), GG 2, GG 11, TMV 2, and AK 12-24 were collected from various sources. The pods of each entry were kept at 55°C temperature in an oven for four hours to kill the hidden infestation of insects, if any. The pods of different entries were then stored in labeled glass containers, the tops of which were covered with muslin cloth and tied firmly with rubber bands for better aeration. The samples were placed in BOD incubator at 30±1°C temperature for 10 days before use.

Ovipositional preference: One hundred fifty gram pods of each variety were placed randomly in a wooden cage (90 x 75 x 60 cm). A petridish (9 x 1 cm) was placed at the centre of the cage for releasing the insects. Fifty pairs of 1 to 2 days old adults were released in the petridish so that the insects had an equal chance of choosing the variety for oviposition. The cage was then covered with

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muslin cloth and tied to avoid the escape of adults. After 7 days, adults were removed from the oviposition cage and observations on orientation and oviposition were recorded. The experiment was conducted in Completely Randomized Design with three replications. To study the influence of groundnut varieties on larval and total developmental preference, the observations were recorded on number of full grown larvae pupated from the total number of eggs kept on each variety, whereas, total developmental preference was recorded by number of adults emerged out from cocoons.

Antibiosis: Eight varieties of groundnut pods were tested for their antibiosis effect against *C. serratus*. A set of 20 pods each having one egg was kept individually in a plastic vial (6.0 x 2.0 cm) with a perforated screw cap and was considered as one replication. Each variety was replicated thrice in a Completely Randomized Design. Observations were recorded in respect of larval, pupal and total developmental period, sex ratio, fecundity, oviposition period and longevity of *C. serratus*. The growth index i.e., percentage of adult emergence/average total developmental period (days) was calculated.

Susceptibility: Dobie (1977) gave an index for describing the susceptibility of different varieties for the development of a species as I = Log e^F / D x 100

Where, F = total number of adults emerged, D = mean developmental period (days) and I = index of susceptibility.

This index was used in comparing the varietal susceptibility of the groundnut cultivars tested to *C. serratus*.

Results and discussion

The eggs laid by *C. serratus* in test varieties were significantly different (Table 1). The lowest number of eggs were recorded on Kadiri 3 followed by GG 2. Significantly highest number of eggs were laid on AK 12-24 followed by TMV 2 and JL 24. The adults were oriented on all groundnut varieties tested with a varied response. Minimum number of beetles was oriented on variety Kadiri 3 and maximum on AK 12-24 followed by TMV-2 which was significantly different than rest of the varieties.

Developmental preference of *C. serratus* was evaluated on the basis of number of pupae and adults developed from eggs. Significant differences were found between the tested groundnut varieties in terms of number of grubs that transformed into pupae. The lowest number of pupae was observed on Kadiri 3 which differed significantly from the rest of the varieties. The highest number of pupae was recorded on the pods of AK 12-24 followed by JL 24. The adult emergence from pods also varied significantly amongst the varieties. The lowest number of adults emerged from Kadiri 3 as against the highest on AK 12-24 followed by JL 24.

Table 1 Ovipositional and developmental preference of *C. serratus* on test varieties of groundnut

Variety	No. of eggs	Orientation of adults on pods	No. of pupae	No. of adults emerged
JL 24	292.0 (2.5)*	9.5 (3.1)**	56.6 (7.5)**	56.0 (7.5)**
Kadiri 3	170.3 (2.2)	4.7 (2.2)	20.7 (4.3)	20.0 (4.5)
ICGS 44	278.3 (2.4)	8.8 (3.0)	44.3 (6.7)	44.0 (6.6)
Smruti (OG 52-1)	225.7 (2.4)	7.4 (2.7)	31.3 (5.6)	31.0 (5.6)
GG 2	204.7 (2.3)	6.2 (2.5)	42.3 (6.5)	42.0 (6.5)
GG 11	209.3 (2.3)	6.3 (2.5)	33.3 (5.8)	33.0 (5.7)
TMV 2	316.0 (2.5)	10.8 (3.3)	52.7 (7.3)	52.0 (7.2)
AK 12-24	332.7 (2.5)	10.9 (3.3)	60.7 (7.8)	60.0 (7.7)
SEm±	0.1	0.2	0.4	0.4
CD (P=0.05)	0.4	0.5	1.1	1.1

* Figures in parentheses are log x transformed values.
** Figures in parentheses are square root transformed value

An overall analysis on the ovipositional preference revealed that *C. serratus* preferred the varieties like AK 12-24, TMV 2 and JL 24 for oviposition, whereas the varieties Kadiri 3 and GG 2 were less preferred. Mittal (1968) reported that the variety TMV 2 was the most preferred for egg laying, while TMV 3 was the least preferred. Rama Devi (1996) revealed that four genotypes viz., TCGS 61, TCGS 88, TCGS 91 and ICGS 11 were less preferred, whereas the genotypes ICGS 29 and JL 24 were highly preferred basing on the number of eggs laid and percentage of adult emergence. Ghorpade *et al.* (1998) reported that maximum number of eggs was observed on JL 24, whereas minimum oviposition by *C. serratus* was noticed in both ICGS 11 and SB 11. Haritha *et al.* (1999) reported genotypes ICG (FDRS 10) and TMV 2 supported higher fecundity, whereas the genotypes ICGS 11 and ICGS 76 caused low fecundity. Therefore, the reports of the aforesaid workers corroborate the present finding.

Antibiosis: The larval duration on different groundnut varieties varied from 40.3 to 46.7 days (Table 2). Larval duration was shorter on the varieties GG 2 (40.3 days), AK 12-24 (40.4 days), ICGS 44 (40.7 days), TMV 2 (41.4 days) and Smruti (42.2), which were at par with each other. The larval duration was prolonged on varieties such as Kadiri 3, followed by GG 11 and JL 24, respectively. Present studies fully corroborate the findings of Pancholi (1993) and Radadia (1996) who also reported shortest larval duration in GG-2, whereas the longest larval duration on RB-90 and Kadiri-3. The pupal period ranged from 16.2 to 19.7 days on test groundnut varieties. Maximum pupal period was recorded on varieties viz., Kadiri 3, Smruti and JL 24 that were at par with each others while, minimum pupal period was recorded on AK 12-24.

Table 2 Development and survival of *C. serratus* on different varieties of groundnut

Variety	Larval period (days)	Pupal period (days)	Average developmental period (days) (AV)	Adult emergence (%) (N)	Growth index (N/AV)
JL 24	43.8	19.7	72.2	19.1	0.3
Kadiri 3	46.7	19.3	74.4	11.9	0.2
ICGS 44	40.7	16.3	66.6	15.7	0.2
Smruti (OG 52-1)	42.2	19.7	70.3	13.2	0.2
GG 2	40.3	16.3	66.5	19.5	0.3
GG 11	43.3	19.5	72.5	15.6	0.2
TMV 2	41.4	18.7	68.1	16.2	0.2
AK 12-24	40.4	16.2	66.5	18.2	0.3
SEm±	0.7	0.3	0.8	0.2	0.0
CD (P=0.05)	2.1	0.7	2.4	0.7	0.1

NB: Mean of three replications

Likewise, the highest developmental period was noticed in Kadiri 3 followed by GG 11 and JL 24 which were at par. On the contrary, the lowest developmental period was recorded on AK 12-24 followed by GG 2 (66.5) and ICGS 44. Rama Devi (1996) noticed the highest developmental period in ICGS-11. Haritha *et al.* (1999) reported the maximum developmental period in FDRS 10 and ICGS 11, while Pancholi (1993) reported the lowest developmental period in GG 2. Therefore, the aforesaid reports were in support of the present finding.

A perusal of the data on survival highlighted that the highest survival was recorded on GG 2, which was at par with JL 24. Conversely, the lowest survival was recorded on Kadiri 3.

The data on growth index (Table 2) revealed that there were significant differences among the test varieties. The highest growth index was recorded on variety GG 2 followed by AK 12-24, JL 24, ICGS 44 and TMV-2. The lowest growth index was recorded on Kadiri 3 followed by Smruti and GG 11. Thus, the results that the varieties exhibited higher growth indices indicated their suitability for the development of the species indicating their susceptibility. Pancholi (1993) also reported that among 13 varieties of groundnut studied for the growth index of *C. serratus*, maximum growth index was noticed in varieties GG 2 and GAUG 10, whereas it was minimum in varieties *viz.*, ICGS 44 and SG 84. Radadia (1996) reported the maximum growth index on GG 2 followed by J 11 and RB 46, whereas minimum was on S5 followed by Kadiri 3 and PBS 8. Rama Devi (1996) reported the highest growth index in JL 24 and the lowest in TCGS 61 followed by ICGS 11.

Pre-oviposition, oviposition and post-oviposition period: Freshly emerged female beetles from test groundnut varieties were studied for their pre-oviposition, oviposition and post-oviposition behaviour. The data gathered on these aspects were summarized in Table 3. The effect of test groundnut varieties on pre-oviposition, oviposition and post-oviposition period was found to be non-significant. However, the shortest pre-oviposition period was recorded on the varieties Kadiri 3 and ICGS 44 whereas the longest pre-oviposition period was recorded on AK 12-24. In case of post-oviposition period, maximum period was recorded on Smruti as against minimum on GG 11.

Table 3 Pre-oviposition, oviposition, post-oviposition period, adult longevity (days) and sex ratio of *C. serratus* on different groundnut varieties

Variety	Pre-oviposition period (days)	Oviposition period (days)	Post-oviposition period (days)	Adult longevity (days)		Sex ratio (M:F)
				Male	Female	
JL 24	1.0	8.4	8.1	13.6	13.6	1:1.1
Kadiri 3	1.0	7.4	7.8	15.3	16.1	1:1.1
ICGS 44	1.0	7.6	7.5	15.6	16.2	1:1.1
Smruti (OG 52-1)	1.0	7.7	9.5	16.1	16.3	1:1.1
GG 2	1.0	8.3	6.3	16.2	16.5	1:1.0
GG 11	1.0	9.8	6.2	17.1	18.1	1:0.9
TMV 2	1.0	8.5	7.8	17.5	20.0	1:1.2
AK 12-24	1.5	8.5	8.1	15.2	16.1	1:1.2
SEm±	1.0	7.9	7.1	16.4	16.1	1:1.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Longevity of adult and Sex ratio: It was evident from the data that there was no significant difference in the longevity of male and female beetles emerged from test groundnut varieties. The sex ratio (male: female) ranged from 1:0.9 to 1:1.2 among the varieties tested, which was non-significant.

Fecundity: Significantly highest fecundity was noticed in the females emerged from variety AK 12-24 which was at par with GG 2 and TMV 2 as against lowest on Kadiri 3 (Table 4).

Table 4 Fecundity and susceptibility idea of *C. serratus* on test varieties of groundnut

Variety	Fecundity/female		
	Maximum	Minimum	Average ± SD
JL 24	83	40	60.0 ± 13.2
Kadiri 3	48	20	35.3 ± 9.0
ICGS 44	74	30	52.0 ± 12.9
Smruti (OG 52-1)	61	22	43.2 ± 10.8
GG 2	93	40	66.3 ± 10.1
GG 11	58	38	45.1 ± 9.4
TMV 2	91	40	65.2 ± 16.4
AK 12-24	93	44	67.5 ± 11.1
SEm±	-	-	1.4
CD (P=0.05)	-	-	3.9

Pancholi (1993) and Rama Devi (1996) had also reported the variation in fecundity of F_1 generation of *C. serratus* in different groundnut varieties. Haritha *et al.* (1999) reported the highest fecundity on TMV 2 and ICGS 44, while the lowest on ICGS 11 and ICGS 76.

Susceptibility: Data on number of adults emerged from different varieties reveled that the lowest number emerged from Kadiri 3, while highest from AK 12-24 and the differences among the varieties were significant (Table 4). Data on index of susceptibility relating to the attack of *C. serratus* to groundnut entries indicated that the variety Kadiri 3 exhibited the lowest index of susceptibility, which was significantly superior to the rest of the varieties studied. On the contrary, significantly the highest index of susceptibility was noticed in AK 12-24 followed by TMV 2.

Table 5 Susceptibility index of groundnut varieties to infestation by *C. serratus*

Variety	Average developmental period (days)	No. of adults emerged	Susceptibility index (I)
JL 24	72.2	56.0 (7.5)*	5.6
Kadiri 3	74.4	20.0 (4.5)	4.0
ICGS 44	66.6	44.0 (6.6)	5.7
Smruti (OG 52-1)	70.3	31.0 (5.6)	4.8
GG 2	66.5	42.0 (6.5)	5.6
GG 11	72.5	33.0 (5.7)	4.8
TMV 2	68.0	52.0 (7.2)	5.7
AK 12-24	66.5	60.0 (7.7)	6.2
SEm±	0.8	0.3	0.2
CD (P=0.05)	2.2	1.1	0.5

* Figures in parenthesis are transformed values

Ghorpade *et al.* (1998) reported the varieties ICGS 11 and SB 11 were less susceptible to *C. serratus*, whereas Haritha *et al.* (1999) reported the lowest and the highest index of susceptibility in ICGS 11 and ICGS 44, respectively.

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Effect of plant growth stages on the behaviour and biology of mustard aphid, *Lipaphis erysimi* (Kalt.)

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Abstract

The settling behaviour, wing formation and biology of mustard aphid *Lipaphis erysimi* (Kalt.) were studied on six cultivars of rapeseed - mustard at three growth stages, i.e., young plant (whole), grown-up plant (leaf) and inflorescence stage plant (twig) under laboratory conditions. The settling of nymphs was higher on inflorescence stage plants than other growth stage. It was maximum on *B. campestris* var. brown sarson (BSH-1) followed by *B. napus* (GSH-1) and *B. juncea* (RH 30) while *E. sativa* (T-27), *B. juncea* (Purple mutant) and *B. carinata* (HC-2) were the least preferred and reverse was true for wing formation. Reproductive period, adult longevity, life span and fecundity/female/day were higher at inflorescence stage plants, irrespective of species. Aphid development was faster on BSH-1; GSH-1 followed by RH 30 and it was slow on *Eruca sativa* T-27, Purple mutant and HC-2.

Key words: Mustard aphid, *Lipaphis erysimi*, settling behaviour, wing formation, *cultivars, growth stages, biology*

Introduction

Oilseed crops occupy an important place in the agricultural economy of India, of which rapeseed and mustard rank at second place after groundnut in terms of area and production. These crops occupied an area of 6.85 m ha with production of 8.36 m. tonnes in 2004-05 (Mangal Rai, 2006). Despite large acreage, the average productivity of oilseeds is very low mainly due to effect of various biotic and abiotic stresses. Out of an array of insect-pests, mustard aphid, *Lipaphis erysimi* (Kalt.) is one of the major constraints in their profitable cultivation. Seed yield losses of 35 to 73.3% have been attributed to mustard aphid in different agroclimatic regions in India (Bakhetia and Sekhon, 1989). *Brassica* cultivars showed great variation in their susceptibility to aphid infestation. Also, phenological stages and morphological/anatomical traits determine the preference of mustard aphid on oilseed brassicae (Rohilla *et al.*, 1990; Rohilla *et al.*, 1993; Rohilla *et al.*, 1999 and Agarwal *et al.*, 1996b), Thus it is imperative to unfold their influence on the behaviour and development of mustard aphid, on rapeseed-mustard crops. These studies give an in site to understand the suitability of different hosts for aphid multiplication.

Material and methods

Six genotypes of rapeseed-mustard belonging to five crops *viz.*, *Brassica campestris* (L.) var. brown 'sarson' (BSH-1), *B. juncea* (L.) Czern & Coss. (cv. RH 30 and Purple mutant), *B. carinata* L. (cv. HC-2), *B. napus* L. (cv. GSH-1) and *Eruca sativa* Mill (cv. T-27) were sown in the field at two times i.e., end of September, to have early availability of aphids and late i.e., second week of November to obtain plant samples of different growth stages till late.

The plant/plant parts of different cultivars at three growth stages i.e., whole young plant at 4-5 leaf stage, third leaf from the apex of main shoot of grown up plant stage (45-50 days old) and 10 cm top inflorescence twig (before flowering initiation) were taken from the field in separate polythene covers and brought to the laboratory. The individual young plants were wrapped above root level in absorbent cotton and plugged in the mouth of glass vial (2.5 x 10 cm) filled with Hoagland solution (a nutrient medium for plants in water for water culture) in such a manner that roots remained inside the medium and vegetative parts outside the vial. A small glass tube was inserted along with the swab to facilitate addition of Hogland solution with the help of wash bottle as and when required. Likewise, leaf and inflorescence twigs were also maintained. This gave rise to formation of new roots in the medium and plants/plant parts remained turgid and healthy.

Maintenance of Stock Culture: The stock culture of mustard aphid was maintained by rearing aphid at each plant growth stage under laboratory conditions at room temperature. The gravid females of mustard aphid were collected from each early sown cultivars from the field. The culture was started by releasing these females on the host plants/parts and nymphs of different age/instars were used for further experimentation.

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Effect of plant stage on settling behavour of mustard aphid: At each stage, one (0 to 12 h old) nymph was released on one plant/plant part of respective cultivar and replicated 30 times. The observations on settling of nymphs were recorded daily upto 5 days. The settling was determined by the presence of nymph on its host at the time of each observation and per cent settling was calculated by using the following formula :

$$\text{Per cent settling} = \frac{\text{Number of nymphs settled/cultivar}}{\text{Number of nymphs initially released/cultivar}} \times 100.$$

Effect of plant stage on alate formation in mustard aphid: Forty freshly laid nymphs had been settled on each cultivar by using replacement technique from the stock culture on respective cultivar. When these nymphs became adults, data on wing formation were recorded on 30 aphids. Per cent wing formation was calculated by using the following formula:

$$\text{Percent alate formation} = \frac{\text{Number of alates formed / cultivar}}{\text{Number of adults formed / cultivar}} \times 100$$

Biology of mustard aphid: The comparative biology of mustard aphid was carried out on six cultivars at three growth stages at room temperature 15±2°C. Gravid females were collected from each cultivar from early sown field crops. One female from each genotype was released on each host and stage maintained in glass vials as explained and replicated 30 times. Next day, all nymphs, except one, and the female were removed from all the replicates. Subsequently, the observations were recorded after every 24 h for various biological parameters. The experiment was replicated 20 times.

Results and discussion

The data presented in Table 1 revealed that nymphs settled quickly on young plant stage two days after release on *B. campestris* var. brown 'sarson' (BSH-1) and *B. napus* (GSH-1) as compared to other hosts on which it settled after three to four days of release. Nymph settling was highest on variety BSH-1 (87.1%) followed by GSH-1 (69.7%). The least preferred hosts were *B. juncea* (Purple mutant) and *E. sativa* (T-27) on which the nymphs settling was very low, i.e., 42.1 and 43.2%, respectively, at 4th day of initial release.

On grown-up plant stage, the maximum number of nymphs got settled on cultivar BSH-1 (86.7%) one day after release followed by GSH-1 (74.6%), two days after release. The lowest settling was recorded on T-27 (50.8%) at four days after release. On the remaining hosts, the nymphs settled on third day after release.

At inflorescence stage, the varieties BSH-1 and GSH-1 were the most favourable hosts with highest settling of nymphs (93.3%, each),

Effect of host plant stage on the settling behaviour of mustard aphid: Notably, the host BSH I was found to be the most suitable for the settling of mustard aphid, irrespective of its three stages, i.e., young, grown-up and inflorescence stage plant followed by GSH-1. T-27, HC-2 and 'Purple mutant' were the least preferred hosts for settling of nymphs (Table 1). Settling of nymphs on grown-up stage plants, irrespective of host, was higher than young stage plants, but lower than inflorescence stage plants. Maximum settling of nymphs, i.e., 93.3% was observed one day after their release on young stage plant (BSH-1) and inflorescence stage plants both of BSH-1 and GSH-1. On the other hosts, the settling was higher at the inflorescence stage plant at two days after release except the cultivar 'Purple mutant' where it was higher on the young plant but three days after release, it also became higher on inflorescence stage. The present findings got full support from the findings of Kundu and Pant (1967), Bakhetia and Sandhu (1973), Bakhetia and Bindra (1977), Rohilla *et al.* (1990), Kher and Rataul (1991), Rana *et al.* (1995), Agarwal *et al.* (1996 a, b) and Rohilla *et al.* (1996) who observed that rapeseed cultivars were preferred more by *L. erysimi* as compared to *E. sativa*. The cultivar 'Purple mutant' and T-27 were the least preferred hosts showing 63.5% settling of nymphs, two days after release.

Effect of host plant stage on the wing formation in mustard aphid: Perusal of data presented in Table 2 indicate that the wing formation of mustard aphid was maximum (17.8 to 40.0%) at young stage of various hosts followed by grownup stage (11.1 to 33.5%) and inflorescence stage (0 to 26.7%). It suggests that inflorescence stage is most preferred by the insect.

At young plant stage, the minimum wing formation (17.8%) was observed on varieties BSH-1 and GSH - 1, which was statistically at par with RH 30 (22.2%). However, wing formation on the hosts RH 30 and HC-2 was on par. Significantly higher wing formation was recorded on cultivars Purple mutant (40%) and T-27 (37.8%), which were on par.

At inflorescence stage, significantly low wing formation, i.e., 0 and 2.2% was observed on BSH-1 and GSH-1, respectively. It was highest (26.7%) on T-27 and at par on Purple mutant (20%) and HC-2 (13.3%). However, wing formation on HC-2 (13.3%) and RH 30 (11.1%) was at par.

The present findings are in accordance to the findings of Bonnemaison (1965), Tripathi *et al.* (1986), Singh *et al.* (1990), Agarwal *et al.* (1996a) and Rohilla *et al.* (1999).

Table 1 Settling of nymphs of mustard aphid, *Lipaphis erysimi* (Kalt.) on different growth stages of rapeseed-mustard crops and cultivars

Genotype	Variety	Plant Stage	Per cent settling of nymphs, days after release (N=20)				
			1	2	3	4	5
Brassica campestris	BSH-1	I	93.3	87.1	87.1	87.1	87.1
var. brown 'sarson'		II	86.7	86.7	86.7	86.7	86.7
		III	93.3	93.3	93.3	93.3	93.3
B. juncea	RH 30	I	73.3	58.6	50.8	50.8	50.8
		II	73.3	63.6	59.3	59.3	59.3
		III	80	80	80	80	80
B. juncea	Local	I	86.7	75.1	45.1	42.1	42.1
(Purple mutant)		II	73.3	63.5	55.1	55.1	55.1
		III	73.3	63.5	63.5	63.5	63.5
B. carinata	HC-2	I	73.3	53.7	50.1	50.1	50.1
		II	73.3	58.6	54.7	54.7	54.7
		III	86.7	86.7	75.1	75.1	75.1
B. napus	GSH-1	I	80	69.7	69.7	69.7	69.7
		II	80	74.6	74.6	74.6	74.6
		III	93.3	93.3	93.3	93.3	93.3
Eruca sativa	T-27	I	86.7	57.8	46.3	43.2	43.2
		II	73.3	58.6	58.6	50.8	50.8
		III	73.3	63.5	63.5	63.5	63.5

I = Young plant (whole), II = Grown-up plant (3rd leaf from apex) and III = Inflorescence stage (10 cm top twig)

Table 2 Wing formation in mustard aphid, *Lipaphis erysimi* (Kalt.) reared on different growth stages of rapeseed-mustard cultivars/crops

Genotype	Variety	Per cent wing formation		
		Young plant (whole)	Grown – up plant (leaf)	Inflorescence stage (twig)
Brassica campestris var. brown 'sarson'	BSH-1	17.8 (24.8)	13.3 (20.1)	0.0 (1.8)
B. juncea	RH 30	22.2 (28.1)	15.5 (23.1)	11.1 (19.3)
B. carinata	HC- 2	26.7 (31.0)	20.0 (26.6)	13.3 (21.4)
B. napus	GSH-1	17.8 (24.8)	11.1 (19.3)	2.2 (6.2)
B. juncea (Purple mutant)	Local	40.0 (39.2)	33.5 (36.6)	20.0 (26.6)
Eruca sativa	T-27	37.8 (37.9)	31.1 (33.9)	26.7 (30.0)
C D (P = 0.05)		(4.92)	(5.76)	(6.69)

Figures in parentheses are angular transformed values

Biology of mustard aphid on various growth stages of different rapeseed - mustard cultivars/crops: Young plant stage: Mustard aphid, *L erysimi* completed four nymphal instars each of the duration of 2.0 to 2.1, 1.9 to 2.0, 1.8 to 2.5 and 2.2 to 3.0 days, respectively, on various hosts with non-significant differences. However, total nymphal period varied significantly ranging from minimum of 7.9 days on BSH-1 to maximum 9.6 days on T-27 (Table 3). Pre-reproductive period was completed in one day on each host. The reproductive period was significantly higher on BSH-1 (17.8 days), GSH -1 (17.5 days) and RH 30 (16.9 days), as compared to the rest of the hosts. This period was significantly lower on Purple mutant (13.9 days) and T-27 (10.6 days). The post-reproductive period ranged from 0.7 to 1.0 day on different hosts with non-significant differences. Significantly lowest adult longevity was recorded on T-27 (12.3 days) followed by 'Purple mutant' (15.6 days), however, it was maximum on BSH-1 (19.8 days) which was statistically on par with GSH - 1 (19.5 days) and RH 30 (18.8 days). Likewise, total life span of mustard aphid varied significantly between 21.9 days on T-27 and 27.7 days on both BSH-1 and GSH - 1. Both of the latter were statistically similar as against T-27.1 days on RH 30 and 26.0 days on HC- 2.

Total fecundity per female was more on those hosts on which the reproductive period was also more. It was

maximum on BSH-1 (90 nymphs) which was statistically on par with GSH - 1 (88 nymphs).

Significantly low fecundity per female was recorded on T-27 (25 nymphs) closely followed by 'Purple mutant' (32 nymphs). Total fecundity per female on HC - 2 was 61 nymphs and on RH 30 was 80 nymphs.

The average fecundity per female per day also varied significantly being minimum, i.e. 3 nymphs each on T-27 and Purple mutant and maximum, i.e., 5 nymphs on BSH-1 which was statistically at par with GSH-1 (5 nymphs) and RH 30 (5 nymphs).

Grown-up plant stage: The durations of first, second, third and fourth instars of *L. erysimi* on various hosts varied from 1.9 to 2.0, 2.0 to 2.1, 2.0 to 2.6 and 2.2 to 3.0 days, respectively, with (Table 4). Total nymphal duration was minimum 8.1 days each on BSH-1 and GSH -1 and maximum 9.7 days on T-27 which was statistically at par with Purple mutant. Pre-reproductive period was completed in just one day irrespective of test hosts. Reproductive period was significantly higher i.e.,19.3 days on GSH - 1 closely followed by 18.7 days on BSH-1 and 18.5 days on RH 30 as compared to 12.8, 14.0 and 14.2 days (statistically at par) on T-27, Purple mutant and HC-2, respectively. Likewise, the post-reproductive period varied significantly ranging from 0.5 days on T-27 to 1.2 days on BSH-1. Adult longevity and total life span were significantly low, i.e., 14.3 and 24.0 days, respectively, on T-27 as compared to 20.9 and 29.0 days, respectively, on BSH-1. However, Purple mutant and HC-2 were statistically on par with T-27 and RH 30 and GSH-1 with BSH-1 for both the parameters.

Total fecundity, i.e., 35 and 42 nymphs/female was significantly low on T-27 and Purple mutant, respectively. However, it was statistically higher, i.e., 120 and 114 nymphs/female on BSH-1 and GSH-1, respectively. Average fecundity of 106 and 64 nymphs/female was recorded on RH 30 and HC-2, respectively. The average fecundity/female/day ranged from 3 (minimum) on T-27 and Purple mutant to 7 nymphs (maximum) on BSH-1 followed by 6 nymphs each on the hosts RH 30 and HC-2, respectively.

Inflorescence stage : Duration of different nymphal instars did not vary significantly between different cultivars, however, total nymphal duration was significantly lower, i.e., 7.9 and 8.1 days each on BSH-1, RH 30 and GSH-1 as against the higher of 8.9, 9.1 and 9.6 days on HC-2, Purple mutant and T-27, respectively (Table 5). Pre-reproductive period was completed in one day on different hosts. Reproductive period differed significantly amongst rapeseed-mustard genotypes being lower, i.e., 14.1, 15.8 and 16.0 days on T-27, Purple mutant and HC-2, respectively, as against 22.2 and 21.9 days on BSH-1 and GSH-1, respectively. Consequently, the female had higher fecundity on more suitable hosts *viz.*, BSH-1 and GSH-1, followed by RH 30 while low fecundity/female was observed on T-27 (37 nymphs), Purple mutant (48 nymphs) and HC-2 (72 nymphs). Average fecundity/female/day followed the same trend being maximum, i.e., 6.1 and 5.7 nymphs on the host BSH-1 and GSH-1, respectively and minimum, i.e., 2.6 and 3.0 nymphs on T-27 and Purple mutant, respectively.

Post-reproductive period varied between 0.7 days on T-27 to.3 days on BSH-1. Adult longevity and life span were significantly higher on BSH-1 and GSH-1 and lower on T-27, Purple mutant and HC-2.

Effect of plant growth stages on the biology of mustard aphid: The perusal of data presented in Table 6 indicated that growth stage of plant did not influence the nymphal duration (8.6 to 8.7 days), pre-reproductive period (one day each) and post reproductive period irrespective of rapeseed-mustard cultivars. However, reproductive period differed significantly being lowest 15.4 days on young plant followed by 16.3 days on grown-up plant and 18.1 days on inflorescence stage plant. Likewise, adult longevity and life span also showed the same trend.

Table 3 Biology of mustard aphid, *Lipaphis erysimi* (Kalt.) on young plant (whole) rapeseed-mustard genotypes under laboratory conditions

Genotype	Variety	Average duration (days)										Average fecundity	
		Nymphal instar					Pre-reproductive	Reproductive	Post-reproductive	Adult longevity	Life span	Per female	Per female/day
		I	II	III	IV	Total							
B. campestris var. brown sarson	BSH-1	2.0	1.9	1.8	2.2	7.9	1.0	17.8	1.0	19.8	27.7	90	5
B. juncea	RH 30	2.0	2.0	2.0	2.3	8.3	1.0	16.9	0.9	18.8	27.1	80	5
B. juncea (Purple mutant)	Local	2.1	2.0	2.2	2.9	9.0	1.0	13.9	0.7	15.6	24.6	32	3
B. carinata	HC-2	2.0	2.0	2.2	2.6	8.8	1.0	15.5	0.7	17.2	26.0	61	4
B. napus	GSH-1	2.0	2.0	2.0	2.2	8.2	1.0	17.5	1.0	19.5	27.7	88	5
Eruca sativa	T-27	2.1	2.0	2.5	3.0	9.6	1.0	10.6	0.7	12.3	21.9	25	3
CD (P=0.05)		NS	NS	NS	NS	0.6	NS	1.8	NS	2.0	2.2	5.8	0.6

Temperature °C (Maximum) = 23.7; Temperature °C (Minimum) = 8.0; RH (%) = 58.9

Table 4 Biology of mustard aphid, *Lipaphis erysimi* (Kalt.) on grown-up plant (leaf) of rapeseed-mustard genotypes under laboratory conditions

Genotype	Variety	Average duration (days)										Average fecundity	
		Nymphal instar					Pre-reproductive	Reproductive	Post-reproductive	Adult longevity	Life span	Per female	Per female/day
		I	II	III	IV	Total							
B. campestris var. brown **sarson**	BSH-1	1.9	2.0	2.0	2.2	8.1	1.0	18.7	1.2	20.9	29.0	120	7
B. juncea	RH 30	2.0	2.0	2.0	2.3	8.3	1.0	18.5	0.8	20.3	28.6	106	6
B. juncea (Purple mutant)	Local	2.0	2.1	2.2	2.5	8.8	1.0	14.2	0.9	16.1	24.9	64	5
B. carinata	HC-2	2.0	2.0	2.0	2.1	8.1	1.0	19.3	1.0	21.3	29.4	114	6
B. napus	GSH-1	2.0	2.1	2.3	2.8	9.2	1.0	14.0	0.8	15.8	25.0	42	3
Eruca sativa	T-27	2.0	2.1	2.6	3.0	9.7	1.0	12.8	0.5	14.3	24.0	35	3
CD (P=0.05)		NS	NS	NS	NS	0.5	NS	2.4	0.4	2.3	2.4	7.7	0.7

Temperature °C (Maximum) = 20.7; Temperature °C (Minimum) = 6.1; RH (%) = 72.1

Table 5 Biology of mustard aphid, *Lipaphis erysimi* (Kalt.) on inflorescence state (twig) of rapeseed-mustard genotypes under laboratory conditions

Genotype	Variety	Average duration (days)										Average fecundity	
		Nymphal instar					Pre-reproductive	Reproductive	Post-reproductive	Adult longevity	Life span	Per female	Per female/day
		I	II	III	IV	Total							
B. campestris var. brown sarson	BSH-1	1.8	2.0	2.0	2.1	7.9	1.0	22.2	1.3	24.5	31.4	136	6
B. juncea	RH 30	1.9	2.0	2.0	2.2	8.1	1.0	18.3	0.9	20.2	28.3	101	6
B. juncea (Purple mutant)	Local	2.0	2.0	2.3	2.8	9.1	1.0	15.8	1.0	17.8	26.9	48	3
B. carinata	HC-2	2.0	2.0	2.3	2.6	8.9	1.0	16.0	0.9	17.9	26.8	72	5
B. napus	GSH-1	1.9	2.0	2.0	2.2	8.1	1.0	21.9	1.0	22.9	31.0	125	6
Eruca sativa	T-27	2.0	2.1	2.6	2.9	9.6	1.0	14.1	0.7	15.8	25.4	37	3
CD (P=0.05)		NS	NS	NS	NS	0.6	NS	2.0	0.3	2.1	2.1	6.3	0.2

Temperature °C (Maximum) = 22.1; Temperature °C (Minimum) = 5.8; RH (%) = 64.3

Table 6 Effect of plant growth stages on the biology of mustard aphid, *Lipaphis erysimi* (Kalt.) irrespective of rapeseed-mustard genotypes

Genotype	Variety	Average duration (days)										Average fecundity	
		Nymphal instar					Pre-reproductive	Reproductive	Post-reproductive	Adult longevity	Life span	Per female	Per female/day
		I	II	III	IV	Total							
Young plant (whole)	HC-2	2.0	2.0	2.1	2.5	8.6	1.0	15.4	0.9	17.2	25.2	63	4
Grown-up plant (leaf)	GSH-1	2.0	2.1	2.2	2.5	8.7	1.0	16.3	0.9	18.3	26.8	80	5
Inflorescence stage (twig)	T-27	1.9	2.0	2.2	2.5	8.6	1.0	18.1	1.0	19.9	28.3	87	5
CD (P=0.05)		NS	NS	NS	NS	NS	NS	1.0	NS	0.8	1.1	2.4	0.2

Temperature °C (Maximum) = 20.7; Temperature °C (Minimum) = 6.1; RH (%) = 72.1

Total fecundity per female was significantly low on young stage plant (63 nymphs) followed by grownup plant (80 nymphs) and highest on inflorescence stage plant (86 nymphs). The average fecundity/female/day was significantly low on young stage plant (4 nymphs) as against other two stages. Inflorescence stage plant was found most suitable for the development of mustard aphid, irrespective of rapeseed-mustard cultivars (Table 6).

The studies are in concurrence with the findings of Kundu and Pant (1967), Bakhetia and Sandhu (1973), Bakhetia and Bindra (1977), Kalra *et al.* (1987), Kher and Rataul (1991), Basavaraju *et al* (1994), Singh *et al.* (1996); Agarwal *et al.* (1996a) and Rohilla *et al.* (1999).

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Morphological traits and phenological stages of promising entries of rapeseed-mustard germplasm *vis-a-vis* mustard aphid, *Lipaphis erysimi* (Kalt.) resistance

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Abstract

The morphological traits of *Brassica* genotypes *viz.*, colour of leaf, stem and flower did not have clear cut impact on mustard aphid, *Lipaphis erysimi* (Kalt.) infestation, except purple and pale green colour of leaves (Purple mutant and TMH-52) and dull yellow and greenish yellow colour of flowers (TMH-52 and *Brassica tournifortii*) exhibited antixenosis to mustard aphid. Duration to flowering initiation, 50% flowering and 100% flowering showed non-significant positive correlation with peak aphid infestation likewise angle of orientation of siliqua to main raceme and number of buds and flowers/main raceme had no effect on aphid infestation except that siliquae oriented widely on raceme invited more aphid population (Pusa Kalyani), while *Brassica nigra* with narrow siliqua angle was resistant to it. The inflorescence raceme dry weight showed positive but non-significant correlation with peak aphid population irrespective of genotypes. The inflorescence dry weight of *B. tournifortii* (8.3%) was significantly less as compared to other genotypes, which was resistant to aphid infestation.

Key words: Morphological traits, phenophages, rapeseed-mustard, germplasm, *Lipaphis erysimi*

Introduction

The average productivity of rapeseed-mustard crops in India is very low than other countries like Sweden, Australia, UK, etc. Three and a half dozen insect pests attack rapeseed-mustard crops, of which mustard aphid *Lipaphis erysimi* (Kalt.) is a major pest causing 35-73% reduction in seed yield (Rohilla *et al* .,1987; Bakhetia and Sekhon, 1989; Kumar,1991). Aphids can be easily managed with insecticides, but their excessive use may lead to development of insecticide's resistant strains, ecological imbalance and other health hazards. Hence the present studies were undertaken to evaluate morphological traits and phenological stages of rapeseed mustard cultivars against mustard aphid infestation.

Material and methods

Twenty two elite genotypes of rapeseed-mustard belonging to six species including T-6342 and RH-7846 as resistant checks and BSH-1 as susceptible check were selected. Theses genotypes were sown in the experimental field in a Randomized Block Design with three replications under two sets of conditions i.e., protected and unprotected. the protected and unprotected sets were randomized within blocks to ensure heavy aphid infestation. The sowing was delayed by 15-20 days then normal for both the years. Fifteen days after germination, thinning was done manually to maintain a distance of 10-15 cm between plants within rows, which were 30 cm apart. Each genotype was sown in plot of 3 rows of 3 m length. All agronomic practices were followed to raise a good crop. As and when protected set of genotypes reached to 20% infestation of central twigs with aphids, the set was sprayed with oxydemeton methyl 0.025 % and subsequent sprays were given at 15 days interval, if required as per Singh and Singh (1989).The insecticidal drifts to the unprotected sets were checked by erecting plastic cloth sheets between two plots.

The observations on the population build up of mustard aphid were initiated from the first day of every standard week starting from flowering initiation till disappearance of aphid /harvesting of the genotypes for both the years. At the notice of aphid incidence, 10 aphid infested plants (central twig) per genotype were tagged. The subsequent observations on the population of mustard aphid (adult + nymphs) were recorded as per Prasad and Phadke (1980), Singh (1982) and Agarwal (1993).Total number of aphid infested plants in each genotype were recorded at three stages (flowering, full flowering and full siliqua setting) and plant infestation (%) per genotype was calculated. The observations on days to flowering initiation, days to 50 % flowering, full flowering, days to complete siliquae formation, pattern of siliquae orientation to main raceme, number of buds and flowers per main shoot and flower colour were recorded as per Singh (1982) , Singh (1986). Fresh and dry weight of 10 identical randomly selected raceme twigs, 15 cm per genotype was recorded.

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Results and discussion

Colour of leaf: Stem and flower did not exhibit any clear cut impact on mustard aphid infestation on various genotypes except purple mutant and pale green colour of *leaves (Purple mutant and TMH-52) and dull yellow and* greenish colour of flower TMH-52 and *B. tournifortii* exhibited antixenosis to mustard aphid.

Duration of flowering and full siliquae formation: Flowering initiation and days to 50 % or full flowering did not produce any impact on aphid infestation. Genotype BSH-1, Pusa Kalyani and GSH-I being early escaped aphid infestation but actually were susceptible to aphid infestation. Flowering duration had nonsignificant positive correlation with aphid intensity over a genotype (Table 1).

Siliqua angle with raceme: Angle of orientation of siliqua on raceme of various genotypes varied significantly between 4.2° to 96.3° (Table 1). Wider the angle of orientation more incidence of aphids was observed. Pusa Kalyani was susceptible to aphids as it had wider angle of flower orientation as compared to *B.nigra* which had very narrow angle and with less aphids.

Inflorescence dry weight: *B tournifortii* had very low drymatter and harboured low aphids (Table 1). Raceme dry weight had positive but nonsignificant correlation with aphid population.

Table 1 **Morphological traits and phenophasis of various *Brassica* genotypes *vis-a-vis* resistance to *L. erysimi***

Species/Genotype	Colour			Flowering duration (days) initiation 50%		50%		100%		Full Pod formation (days)	
	Leaf	Stem	Flower	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
B. juncea											
Shiva	Pale green	Pale green	Yellow	65	72	69	77	75	82	94	100
B-294	Pale green	Pale green	Yellow	66	78	72	83	78	87	93	101
B-384	Green	Green	Yellow	78	78	86	82	91	87	103	104
B-463	Pale green	Pale green	Yellow	80	81	87	84	94	88	107	105
JMG-211	*Pale green*	*Pale green*	Yellow	80	82	87	86	94	91	108	106
JMG-212	Pale green	Pale green	Yellow	67	77	75	82	81	89	95	106
JMG-224	Pale green	Pale green	Yellow	65	73	70	78	75	83	93	98
UUR-62	Pale green	Pale green	Yellow	67	77	73	81	79	87	98	105
PCR-10	Green	Green	Yellow	67	81	73	85	79	89	92	100
Varuna (**albino)**	Pale green	Pale green	Yellow	80	78	86	82	91	87	103	100
RWH-1	Greenish white	Greenish white	Yellow	79	80	87	83	93	88	102	100
RW-32-2	Green	Green	Yellow	61	70	67	76	73	81	92	99
RC-199(**apetalous)**	Pale green	Pale green	Yellow	63	83	86	88	92	91	104	105
RC-1425	Pale green	Pale green	Yellow	62	70	69	76	74	81	97	103
RH-7846	Pale green	Pale green	Yellow	61	66	66	71	73	76	95	99
T-6342	Pale green	Pale green	Yellow	55	70	61	75	69	80	89	100
Purple mutant	Purple	Purple	Yellow	82	86	88	91	94	94	105	106
B.campestris											
Pusha kalyani	Dark green	Dark green	Bright yellow	51	58	59	64	66	70	90	96
BSH-1	Pale green	Pale green	Bright yellow	54	54	63	60	70	66	96	93
B. napus cv.GSH-1	Dark green	Dark green	Dull yellow	62	64	68	71	73	78	96	101
Eruca sativa cv.TMH-52	Pale green	Pale green	Pale green	64	66	70	73	76	78	100	105
B.nigra cv. local	Pale green	Pale green	Pale green	67	73	75	78	80	83	102	105
B.tournifortii cv.local	Green	Green	Pale green	62	71	68	76	75	82	90	98
S Em ±				0.05	0.4	0.5	0.6	0.6	0.8	0.8	0.9
CD (*P=0.05*)				1.4	1.2	1.5	1.7	1.7	2.4	2.2	2.6
r with peak aphid population				0.174	0.431	0.114	0.376	0.105	0.130	0.004	0.123

Table 1 (Contd...)

Species/Genotype	Silique angle		Flower buds/ main raceme		Raceme drymatter (%)		Aphids/plant	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
B. juncea								
Shiva	44.2	43.1	60	59	11.5	11.4	129	563
B-294	33.8	32.9	57	55	12.1	12.0	76	372
B-384	4.8	4.2	40	43	11.8	11.9	93	808
B-463	40.5	42.8	37	37	9.1	8.9	61	650
JMG-211	38.8	36.0	51	45	10.4	10.6	28	649
JMG-212	42.9	41.3	60	57	12.6	12.7	37	422
JMG-224	42.1	42.3	59	58	10.3	10.0	102	408
UUR-62	42.5	44.0	42	44	12.0	12.0	9	594
PCR-10	39.2	40.2	47	49	11.0	11.0	99	737
Varuna (albino)	39.6	38.0	39	38	13.0	12.7	142	462
RWH-1	44.6	45.2	47	43	10.9	10.7	133	912
RW-32-2	45.5	43.5	45	44	11.7	11.8	66	229
RC-199(apetalous)	35.4	35.0	43	42	10.8	11.0	142	502
RC-1425	43.8	42.2	96	92	12.0	12.1	79	388
RH-7846	39.2	38.6	46	43	13.1	12.8	91	548
T-6342	43.0	41.1	49	45	9.5	9.7	93	575
Purple mutant	45.4	47.3	50	46	10.8	10.7	31	148
B.campestris								
Pusha kalyani	78.0	75.1	57	54	10.2	10.0	97	281
BSH-1	61.3	61.8	58	55	10.5	10.4	79	246
B. napus cv.GSH-1	68.5	69.8	49	50	9.1	9.0	38	423
Eruca sativa cv.TMH-52	15.7	15.4	35	31	9.3	9.1	18	35
B.nigra cv. local	5.4	5.3	81	81	13.1	13.3	65	228
B.tournifortii *cv.local*	45.0	47.5	19	18	8.3	8.3	6	168
S Em ±	2.1	1.4	3.3	3.5	0.2	0.1		
CD (P=0.05)	3.9	3.9	9.4	10.1	0.5	0.3		
r with peak aphid population	0.022	0.025	0.172	0.055	0.137	0.140		

Purple foliage (Purple mutant), pale green foliage (*E. sativa*), dull yellow colour of flowers (TMH-52 *E.sativa*) showed antixenosis to *L. erysimi*. Duration of flowering did not have any clear cut impact on aphid infestation except that early flowering permitted escape of aphids over a genotype. Genotypes with wide angle of buds orientation on raceme showed susceptibility to aphis as against the genotypes with narrow angle of orientation. Density of buds on raceme found to have positive association with aphid infestation. Present studies are in agreement with Narang (1982) and Agarwal (1993) who did not find any relationship between aphid resistance and angle of orientation of flower buds on inflorescence raceme. However, are in partial agreement with Yadav *et al.* (1985) and Chatterjee and Sengupta (1987) who reported that glossy foliage and white petals imparted resistance to aphid infestation. It may be probably due to less number of representatives in each category which masked their impact on aphid reaction to them.

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Predatory potential of lady bird beetle, *Coccinella septempunctata* L. on mustard aphid, *Lipaphis erysimi* (Kalt.)

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Abstract

The grub of *Coccinella septempunctata* consumed a total of 20.67, 64.50, 171.43 and 299.82 aphids (nymphs and adults) during first to fourth instars, respectively. On an average male consumed less, i.e., 118.93 aphids as against the 127.68 aphids/day by female in their respective life spans. When fixed number of aphids were provided as prey to know number of predators in pairs, it was observed that single male ad female took more time, i.e., 19.2 and 16.6 days, respectively as against only 4.6 days required to consume 9 aphids colonies (on an average *100 to 150 aphids/colony) of the prey by three pairs of* predators.

Key words: Efficacy, lady bird beetle, mustard aphid

Introduction

The mustard aphid, *Lipaphis erysimi* (Kalt.) is the most serious pest of rapeseed-mustard crops. Although the control of mustard aphid by use of systemic insecticides is quite easy (Singh and Singh, 1987), but, their indiscriminate use has resulted in plethora of problems like pesticides residue in oil and cakes, mortality of natural enemies, insecticidal pollution leading to various health hazards and the increased cost of cultivation, etc. Nevertheless, concreted efforts have not been made in the past to combine the various aspects of management, which is important to achieve cost effective control of aphis. It has now become imperative to reduce the application of insecticides with the adoption of biological control tactics in a compatible manner, so as to keep the pest population below economic injury level. The coccinellids have been reported to be effective for controlling the mustard aphid *L. erysimi* (Kalra, 1988). The present studies were conducted to assess the efficacy of lady bird beetle, *C. septempuctata* on mustard aphid.

Material and methods

The observation on the potentiality of lady bird beetle, *C. septempunetata* to consume mustard aphid was determined under the laboratory conditions. The predatory potential consisting of five different combination, i.e., one female, one male, one pair, two pairs and three pairs was tested and replicated thrice. In each case, 9 aphid colonies (100-150 aphids/colony) were provided in glass battery jars (15 x 20 cm). The observation on consumption of aphids by lady bird beetle were recorded after every 24 hrs, till complete consumption of aphids and the number of days required to consume the released aphids by lady bird beetle adult were calculated. For studying the potentiality of grubs of lady bird beetle, the freshly emerged grubs (upto 12 hrs old) were released in petridishes (5 cm diameter). The aphids collected from unsprayed field were provided as food for grubs. The known number of aphids (nymphs and adults) along with fresh leaves/inflorescence of mustard was provided to *each predator after every 24 hrs. The unconsumed aphids* were counted at every 24 hrs to find the actual number of *aphids consumed by various stages and the average* number of aphids consumed by the predator was calculated.

Results and discussion

The data presented in Table 1 indicated that first, second, third and fourth instar grubs in their total life duration consumed 20.67, 64.50, 171.43 and 299.82 aphids (nymphs and adults), respectively. It was observed that predation rate of grubs increased with the stage i.e., 12.30, 32.25, 64.21 and 93.69 aphids by first, second, third and fourth instar grubs/day, respectively. The beetle *C. septempunctata* was found to be very effective predator of *L. erysimi* under laboratory condition at average temperature of 24.1°C and 76% relative humidity.

In grub stage the beetle on an average consumed 557.4 aphids in the total life duration of 9.55 days with an average of 58.37 aphids/day. The male and female adults on an average consumed 118.93 and 127.68 aphids (nymphs and adults)/day, respectively. In general female consumed more aphids as compared to males. Sundby (1966) and Singh (1993) reported that *C. septempunctata* grub consumed 412 to 594 individuals of *L. erysimi* in its life span, respectively. They also reported that predatory potentiality of *C. septempunctata* increased with the increased age and stage of predation.

When fixed number of aphids were provided as prey to known number of predators. It was observed that single male and female of *C. septempunctata* took more time i.e.,

19.2 and 16.6 days, respectively as against only 4.6 days required to consume same number of prey by three pairs of predators in caged conditions (Table 2).

This shows that higher population of predators is required to avoid economic loss in seed yield consequent upon the increasing number of aphids/day in the absence of predators. Earlier, Sundby (1966), Atwal *et al.* (1971), Singh (1982) and Singh (1993) also reported it as the effective predator of mustard aphid.

Table 1 Predatory potentiality of lady bird beetle, *C. septumpunctata* on mustard aphid, *L. erysimi* (Kalt.)

Stage	*Average duration of instars/stage (days)	Average number of aphids consumed in life	Average number of aphids consumed/day/individual
1st instar grub	1.68 (1-2)	20.67	12.30
2nd instar grub	2.00 (2)	64.50	32.25
3rd instar grub	2.67 (2-3)	171.82	64.21
4th instar grub	3.20 (3-4)	299.82	93.69
Total	9.55 (8-10)	557.42	58.37
Adult			
Male	21.67 (18-24)	2577.21	118.93
Female	24.83 (19-30)	3170.29	127.68

* Average based upon 30 observation

Table 2 Predatory potentiality of adult ladybird beetle, *C. septumpunctata* alone and pairs of mustard aphid, *L. erysimi* (Kalt.)

Treatment	No. of aphid colonies*	No. of days required to consume whole colonies of aphids
1 Male	9	19.2 (18-21)**
1 Female	9	16.6 (16-18)
1 Pair (male + female)	9	13.6 (13-15)
2 Pair (male + female)	9	8.4 (7-9)
3 Pairs (male + female)	9	4.6 (4-6)
CD (P=0.05)	-	0.9

* A colony of mustard aphid contained about 100 to 150 aphids
** Range in days

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Sources of resistance against *Alternaria* blight and white rust in rapeseed-mustard for north-western Himalayas

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Abstract

Sixty three germplasm lines of rapeseed-mustard belonging to *Brassica rapa* L. (Syn. *B. campestris* L.), *B. napus* L., *B. juncea* (L.) Czern and Coss and *B. carinata* Braun were artificially screened against *Altenaria* blight and white rust under field conditions. Significant variability in the severity of these diseases was observed among genotypes. Genotypes JEY-03, Parkland and Span (*B.rapa*), Hira and JMM-95-5 (*B. juncea*) were observed resistant to white rust disease. Genotypes PHR-1 and PHR-2 (*B. juncea*), PBN-2001 and PBN-2002 (*B. napus*) and PBC-9221 and PCC-5 (*B. carinata*) showed lower severity of *Alternaria* blight at the leaf as well as siliqua stage. All the genotypes belonging to *B. napus* and *B. carinata* showed resistance to white rust.

Key words: White rust, *Alternaria* blight

Introduction

Rapeseed-mustard are an important group of oilseed crops constituting almost 13.2% of the world's edible oil requirement. These have wide adaptability and are often grown under varied agro-climatic conditions throughout the world. Although, cultural, agronomic and environmental factors are responsible for low productivity but occurrence of pests and diseases is an important and established yield destabilizing factor in these crops. Yield losses up to 10-70% due to *Alternaria* blight (Gupta *et al.*, 2003); 27.2% and 89.8% due to leaf and staghead phase of white rust, respectively (Lakra and Saharan, 1989) have been reported. Little efforts have been made so far to find out the sources of resistance against these important diseases in different species of rapeseed-mustard except fungicidal management. Therefore, present studies were conducted to find out the sources of resistance against *Alternaria* blight and white rust diseases in rapeseed-mustard.

Material and methods

Sixty three promising germplasm lines of rapeseed-mustard belonging to *Brassica rapa* L. (Syn. *B. campestris* L.), *B. juncea* (L.) Czern and Coss, *B. napus* L. and *B. carinata* Braun (Table1) were artificially screened against major diseases under field conditions during post-rainy seasons of 2002-03 and 2003-04 as per Kumar and Saharan (2002). In order to create severe natural epidemic of diseases, the germplasm lines were planted during first week of November, in single row of 3 m length each with a row of susceptible check Varuna after every test entry in two replications.

The recommended doses of fertilizers were applied and a spacing of 30 cm between the rows and 10 cm between the plants was maintained. Fields were irrigated from time to time to maintain high humidity levels for favouring the development of diseases. The crop was artificially inoculated with white rust pathogen *A. candida* with its zoosporangial suspension was prepared after collecting white rust infected leaves from the naturally infected crop of mustard cv. Varuna. The sporangial mass was harvested with the help of a needle and brush in petri plates. Sporangial suspension was prepared in sterile distilled water and incubated in the BOD at 5°C for 5 hr and kept at room temperature (20-25°C) for 2 hr for the successful release of zoospores. The zoospore suspension was adjusted to approximately (1.5×10^4/ml) as per the technique of Verma and Petrie (1978). Inoculation was done at the seedling (30 DAS) and flowering stages (60 DAS) with the help of pneumatic knapsack sprayer after the preparation of inoculum. Pure culture of *A. brassicae* was obtained on V-8 medium (200 ml tomato juice, 40 mg Rose Bengal, 0.75 g $CaCO_3$, 20 g agar-agar and final volume made to one litre by adding sterilized distilled water). The crop was inoculated on 45 days after sowing with conidial suspension ($4\text{-}5 \times 10^5$ spores/ml) of *A. brassicae* obtained from 10-day old pure culture of the pathogen for successful infection on leaves. For infection on pods, the plants were again inoculated at siliquae formation stage.

The scoring of *Alternaria* blight and white rust diseases at leaf and inflorescence stages was done as per the method of Conn *et al.* (1990) and disease index was calculated as per the formula given by Gupta *et al.* (2003). Percent staghead intensity was assessed by counting the number of infected and healthy inflorescences per row.

Results and discussion

Indian colza (*B. rapa*): The disease intensity of *Alternaria* blight at the leaf stage in different genotypes of Indian colza (*B. rapa*) ranged from 50.2-63.6% (Table 1). Though, all the genotypes showed susceptibility to the disease, but lowest disease was observed in YSPB-24 followed by Pusa Gold, MYSL-204 and JEY-03. There was no significant variation in the disease intensity of *Alternaria* blight at the siliquae stage. It varied from 47.0-55.4% in different genotypes. The higher disease in different genotypes of *B. rapa* at the leaf as well as siliquae stage has been reported by Kumar and Saharan (2002). The disease intensity of white rust at leaf as well as inflorescence stage ranged from 0-30.6%. Genotypes like JEY-03, Parkland and Span remained free from leaf as well as staghead infection of white rust. Earlier Kumar and Saharan (2002) have reported the genotypes Candle, Span, Tobin and YSPB-24 of *B. rapa* to be resistant to white rust. However, Tobin and YSPB-24 showed white rust infection under our conditions, which may be due to prevalence of different races of the pathogen under these conditions.

Indian mustard (*B. juncea*) : Disease intensity of *Alternaria* blight on leaves on different varieties of mustard ranged from 45.5-71.0% (Table 2). Least intensity of disease on leaves was observed in case of genotypes PHR-2(45.5%) followed by PHR-1(45.9%). Similarly, a significant variation with respect to *Alternaria* blight was also observed at the siliquae stage. The disease intensity ranged 19.9-47.3% in different genotypes. The lowest disease (19.9%) on siliquae was recorded in PHR-2 followed by PHR-1(24.7%). Present studies confirm the findings of Vishwanath and Kolte (1999) regarding the tolerance of genotypes of *B. juncea* namely PHR-1 and PHR-2 to *Alternaria* blight. The white rust on leaves ranged 0-45.7% on leaves and 0-7.4% at the staghead stage. The genotype Hira of mustard was found free from white rust disease at the leaf as well as inflorescence stage whereas another genotype namely JMM-95-5 remained free from staghead infection and had also very less disease (5.1%) on leaves.

Swede rape (*B. napus*) : Percent intensity of *Alternaria* blight ranged 37.2-54.2 on leaves and 21.8-41.0 on siliquae (Table 3). Least disease intensity on leaves was recorded in case of PBN-2002(37.2%) followed by PBN-2001(38.6%). Similarly, lowest infection of *Alternaria* blight on siliquae was observed in PBN-2002 (21.8%) followed by PBN-2001 (22.8%). The genotypes PBN-2001 and PBN-2002 showed field resistance to *Alternaria* blight disease at the leaf as well as pod stage. Earlier, *B. napus* genotypes like GS-7027, Midas and Tower have been reported to have resistance to this disease (Dang *et al.*, 2000). The tested genotypes of *B. napus* were found completely free from white rust disease. Similar observations regarding behavior of *B. napus* to white rust have been made by Kumar and Saharan (2002).

Ethiopian mustard (*B. carinata*): The disease intensity of *Alternaria* blight on leaves of Ethiopian mustard ranged from 36.4-50.8% (Table 4). The disease on leaves was lowest in case of PBC-9221(36.4%) followed by PCC-5(37.6%). In general, disease was low on siliquae in all the tested genotypes of *B. carinata*. It ranged 10.8-20.5% in different genotypes. Least disease was recorded in PBC-9221(10.8%) followed by PCC-5(12.0%). The genotypes PBC-9221 and PCC-5 showed field resistance to *Alternaria* blight disease at the leaf as well as siliquae stage. Pathak and Godika (2002) have reported multiple disease resistance to powdery mildew (*Erysiphe cruciferarum*), *Sclerotinia* rot (*Sclerotinia sclerotiorum*), white rust and *Alternaria* blight diseases in PBC-9221. All the genotypes of *B. carinata* were observed free from white rust disease at the leaf as well as inflorescence stage. Similar observations on resistance of *B. carinata* to white rust have also been made by earlier workers (Kumar and Saharan, 2002).

Genotypes JEY-03, Parkland and Span (*B. rapa*), Hira and JMM-95-5 (*B. juncea*) were observed resistant to white rust disease, but these genotypes were susceptible to *Altenaria* blight. Mustard genotypes like PHR-1 and PHR-2 showed least severity of *Altenaria* blight, but found susceptible to white rust disease. Similar observations have been made by Kumar and Saharan (2002) in *B. rapa* as they have reported none of the genotype to possess resistance to all the three diseases *viz.*, *Alternaria* blight, white rust and powdery mildew. Genotypes PBN-2001 and PBN-2002 (*B. napus*) and PBC-9221 and PCC-5 have been found to possess resistance to both the diseases (*A. brassicae* and *A. candida*) under mid-hills of Himachal Pradesh. Therefore, these genotypes identified could be used in future breeding programme to introgress the resistant genes for *Alternaria* and white rust diseases in order to develop resistant genotypes for mid-hill conditions of Himachal Pradesh.

Table 1 Reaction of different genotypes of Indian Colza (*Brassica rapa*) to *Alternaria* blight and white rust (pooled over two years)

Genotype	Percent disease intensity*			
	Alternaria blight		White rust	
	Leaf stage	Siliqua stage	Leaf stage	Inflorescence stage
***B. rapa* var. yellow sarson**				
NDYS-2	58.5(49.9)	47.0(43.3)	21.9(27.9)	6.1(14.2)
JEY-03	52.5(46.4)	50.0(45.0)	0(0)	0(0)
Pusa Gold	50.6(45.3)	49.9(45.0)	20.8(27.1)	5.5(13.4)
YST-151	60.2(50.9)	50.4(45.2)	22.8(28.5)	5.2(13.1)
YSPB-24	50.2(45.1)	49.2(44.5)	19.6(27.2)	5.3(13.2)
MYSL-204	51.3(51.3)	46.6(43.1)	20.6(27.0)	5.6(13.6)
MYSL-208	62.3(52.1)	53.6(47.1)	21.0(27.2)	6.2(14.3)
HPYS-4	60.7(50.2)	55.1(48.0)	12.8(20.9)	1.9(7.7)
Kangra local	62.0(52.0)	55.4(48.1)	30.6(33.6)	3.4(10.6)
NDYS-9602	61.1(51.4)	50.2(45.1)	20.8(27.1)	5.1(12.9)
***B. rapa* var. brown sarson**				
Parkland	63.6(52.9)	49.1(44.5)	0(0)	0(0)
Tobin	61.1(51.4)	49.2(44.6)	20.0(26.5)	0.2(1.0)
Span	58.0(49.6)	48.2(44.0)	0(0)	0(0)
Reward	60.8(51.3)	48.0(43.9)	17.5(24.8)	0(0)
CD(P=0.05)	4.0	NS	4.1	1.1
CV (%)	3.8	4.7	9.0	9.7

*Figures in parenthesis are arc sine transformed values.

Table 2 Reaction of different genotypes of Indian mustard (*Brassica juncea*) to *Alternaria* blight and white rust (pooled over two years)

Genotype	Percent disease intensity*			
	Alternaria blight		White rust	
	Leaf stage	Siliqua stage	Leaf stage	Inflorescence stage
PCR-7	65.4(54.2)	45.2(42.2)	38.6(38.4)	4.7(12.5)
RCC-4	63.8(53.1)	44.6(41.8)	37.3(37.6)	6.0(14.1)
RH-8784	62.2(52.1)	44.1(41.5)	39.8(39.1)	3.0(9.9)
Zem-1	56.1(48.5)	38.9(38.9)	33.1(35.1)	5.4(13.4)
Domo	58.8(50.1)	44.8(41.9)	22.9(33.5)	5.7(13.7)
Varuna	64.3(53.4)	47.3(43.4)	43.9(41.4)	5.7(13.8)
PS-2	71.0(57.6)	45.1(42.1)	36.5(37.2)	5.3(13.1)
RH-97-1	60.1(50.8)	45.6(42.4)	33.4(35.3)	5.3(13.2)
Hira	69.0(56.3)	45.1(42.1)	0(0)	0(0)
BJ-1058	63.8(53.1)	44.7(42.0)	44.0(41.5)	3.3(10.3)
JM-1	67.0(55.0)	43.0(40.9)	24.2(29.3)	2.4(8.8)
BIO-902	59.4(51.5)	46.0(42.7)	32.1(34.5)	4.1(11.5)
KBJ-80	62.3(52.1)	44.4(41.7)	34.8(36.1)	4.6(12.2)
Kranti	63.7(52.90	45.8(42.5)	43.5(41.2)	6.4(14.5)
RC-781	59.4(50.5)	42.9(40.8)	44.1(41.6)	6.2(14.3)
RL-1359	62.0(51.9)	46.9(43.2)	45.7(42.5)	7.4(15.7)
PHR-1	45.9(42.6)	24.7(30.8)	32.2(33.1)	4.6(12.2)
PHR-2	45.5(42.4)	19.9(26.5)	33.2(35.1)	4.6(12.1)
KBJ-78	57.0(49.1)	42.4(40.5)	17.8(24.9)	1.2(6.1)
KBJ-79	61.8(51.8)	44.2(41.6)	18.8(25.6)	1.6(7.1)
Zem-2	55.3(48.1)	38.8(38.5)	20.9(27.1)	1.5(6.8)
JMM-95-5	66.3(54.5)	44.5(41.7)	5.1(12.9)	0(0)
CD(P=0.05)	5.7	4.9	4.2	2.4
CV (%)	5.3	5.8	6.2	10.4

*Figures in parenthesis are arc sine transformed values.

Table 3 Reaction of different genotypes of Swede rape (*Brassica napus*) to *Alternaria* blight (pooled over two years)

Genotype	Percent disease intensity(*Alternaria* blight)	
	Leaf stage	Siliqua stage
HNS-9605	48.2(43.9)	38.8(38.5)
GSC 3A	51.6(45.9)	35.7(36.7)
HNS-9601	47.4(43.5)	29.6(32.9)
PBN-2001	38.6(38.3)	22.8(28.4)
PBN-2002	37.2(37.5)	21.8(27.8)
Wester	54.2(47.4)	38.6(38.4)
ONK-2	46.2(42.8)	35.3(36.4)
Sheetal	46.3(42.8)	35.4(36.4)
HNS-9582	46.5(42.9)	26.1(30.7)
GLS-129	49.6(43.2)	35.0(36.2)
GLS-2027	50.2(45.1)	37.2(37.6)
GLS-6016	52.3(46.3)	33.1(35.1)
ONK-3	48.4(43.2)	32.5(34.7)
GLS-9124	49.4(44.6)	33.7(35.4)
ONK-4	50.4(45.2)	39.2(38.7)
GLS-9129	47.0(43.2)	39.8(39.1)
ISN-129	46.8(43.1)	39.8(39.1)
GLS-6001	46.5(43.0)	38.8(38.5)
Neelam	50.5(45.3)	41.0(39.8)
Hyola-401	43.7(41.3)	37.9(38.0)
CD(P=0.05)	3.8	4.0
CV (%)	4.2	5.3

*Figures in parenthesis are arc sine transformed values.

Table 4 Reaction of different genotypes of Ethiopian mustard (*Brassica carinata*) to *Alternaria* blight (pooled over two years)

Genotypes	Percent disease intensity(*Alternaria* blight)*	
	Leaf stage	Siliqua stage
KSC-9436	47.4(43.5)	18.3(25.3)
HPC-5	48.0(43.6)	18.0(25.1)
KSC-9429	50.8(45.5)	20.5(26.8)
HPC-9419	47.6(43.6)	20.5(26.9)
PCC-5	37.6(37.8)	12.0(20.2)
PBC-9221	36.4(37.0)	10.8(19.1)
DLSC1	49.9(44.9)	19.7(26.4)
CD(P=0.05)	5.4	3.8
CV (%)	5.3	6.5

*Figures in parenthesis are arc sine transformed values.

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Exploitation of fluorescent *Pseudomonas* as biocontrol agent (BCA) against *Macrophomina phaseolina*

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Abstract

***Pseudomonas* species were isolated from the native rhizosphere of groundnut (*Arachis hypogaea* L.) and some of the rhizobacterial isolates were found to have antagonistic activity against *Macrophomina phaseolina*, a root rot pathogen of groundnut plants. Among all the isolates, the two isolates P_7 and P_9 found to show the highest antifungal activity and reduced the mycelial growth to 62.5% and 80.0% respectively were selected for the production of HCN and siderophores. The above isolates produced siderophores and HCN on casamino acid agar (CAA) and *Pseudomonas* fluorescein agar (PFA) media, respectively. Inoculation of *P. fluorescens* (P_9) induced resistance against *M. phaseolina* and observed 60% of reduction in disease incidence after sowing by seed treatment. Study suggested that the rhizobacterial fluorescent *Pseudomonas* spp. as a potential biocontrol agent against *M. phaseolina uner* both *in vitro* and *in vivo* conditions.**

Key words: *Pseudomonas fluorescens*, groundnut, *M. phaseolina*, biocontrol, siderophores

Introduction

Pseudomonas spp. constitute a major group of rhizobacteria among large and heterogenous bacterial population. Fluorescent *Pseudomonads* commonly isolated from rhizosphere have been shown to protect plants from fungal infection (O' Sullivian and O' Gara, 1992; Latha *et al.*, 1992). Biological control of plant diseases using antagonistic bacteria may be considered as a promising alternative to the use of some hazardous chemical fungicides. Production of lytic enzymes and siderophores, biosynthesis of antibiotics, competition for substrates in the rhizosphere, production of hydrogen cyanide are the major mechanisms proposed for the antagonistic activities of fluorescent *Pseudomonads* against plant pathogens (Meena *et al.*, 2000).

Siderophores are extracellular low molecular weight having high affinity iron (III) chelators that transport iron into bacterial cell (Neilands, 1981) thus making it unavailable to pathogens. Siderophores also act as growth promotion factors and some are potent antibiotics. These siderophores are involved in biological control of disease (Sindhu *et al.*, 1997).

Pseudomonads which are present predominantly in the soil have the ability to colonize rhizosphere of a wider vary of crops including cereals, pulses, oil seeds and vegetables (Johri *et al.*, 1997). These properties collectively lead to suppression of pathogens and help in improvement of crop yields. This study focus attention on the exploitation of a fluorescent Pseudomonas as a potent biological control agent of an important soil - borne plant pathogen *Macrophomina phaseolina*, the incitant of root rot of groundnut.

Materials and methods

Organisms: Fluorescent *Pseudomonads* were isolated from the healthy roots and rhizosphere soil of groundnut (*Arachis hypogaea* L.) on King's medium B (KB) (King *et al.*, 1954) and characterized through microbiological and biochemical tests listed in Bergey's Manual of Systematic Bacteriology.

The pathogen *M. phaseolina* was isolated from the infected roots of groundnut plants using potato dextrose agar medium. The *in vitro* antagonistic property of *Pseudomonas* strains as well as siderophores against fungi was tested by dual culture plate technique.

Siderophore production: *Pseudomonas* strains were inoculated separately into succinate medium and casamino acid medium at 1% (v/v) inoculum level and were grown with shaking at 28±1°C (180 rpm) in an incubator shaker for 48 h. After incubation, each culture was centrifuged at 10,000 x g for 20 min at 4°C and the cell-free culture supernatant was examined spectrophotometrically using Shimadzu double beam UV visible spectrophotometer (Jalal and Van der Helm, 1991). Qualitatively the siderophores were detected by using standard chrome Azurol assay technique.

HCN Production: Production of hydrogen cyanide (HCN) was tested qualitatively according to the Method of Mondal *et al.* (1999). The P_7 and P_8 isolates were inoculated in the

iron added pseudomonas agar for fluorescence (PAF) supplemented with the amino acid glycine (4.4 g/l of medium). A strip of sterilized filter paper saturated with a solution containing picric acid (yellow) 0.5% and sodium carbonate (2.0%) was placed in the upper lid of the petri dish. The petri dishes were then sealed with para film and incubated at 28°C for 4 days. A change of colour of the filter paper strip from yellow to light brown, brown or reddish brown was recorded as weak (+), moderate (++) or strong (+++) cyanogenic potential, respectively.

Effect on germination and seedling vigour: A pot culture experiment was conducted using TMV 2 groundnut variety to study the seed bacterisation on seed germination, plant biomass and disease incidence by *M. phaseolina*. Based on *in vitro* antagonism the potential *Pseudomonas* isolates which caused maximum inhibition of *M. phaseolina* were employed for green house and field experiments.

Seed bacterization: Seeds were surface sterilized with 0.1% mercuric chloride for 2-3 min, rinsed in sterile distilled water and dried. Seeds were coated with bacterial isolates suspended in 1% carboxymethyl cellulose in the form of slurry and air dried for 20-22 hrs. The bacterial population was adjusted to 9 x 10^8 CFU / seed.

Sowing of bacterised seeds: Bacterised seeds (treated with *Pseudomonas*) of TMV 2 were sown @ 10 seeds/pot (22.5cm) containing soil infested with *M. phaseolina*. The observations on per cent seed germination, plant biomass and percentage of disease incidence were recorded 15 days after sowing.

Field experiment: A field experiment was laid out in a Randomized Block Design with three replications to find out the effect of *Pseudomonas* on *M. phaseolina* as seed treatment for control of root rot of groundnut variety TMV 2. The plot size was 5.0 x 2.7 m with the spacing of 45 x 20 cm. *M. phaseolina* grown in half cooked maize seed was added in furrows @ 50 g/m before sowing. Seed treatment with antagonists was done by treating the seeds with 1% CMC preparation of antagonists @ 5.0 g/kg seed. Disease incidence was recorded periodically and yield was recorded at harvesting time.

Results and discussion

Thirty isolates of rhizobacteria were isolated from the rhizosphere soil and root samples of groundnut plants. Two isolates P_7 and P_9 showed maximum inhibitory activity against the pathogen *M. phaseolina* (Table 1). The results of morphological, physiological and biochemical tests of the above two strains indicated that the strain belongs to the genus *Pseudomonas* and fall in the fluorescens group.

Autifungal activity: In *in vitro* plate assays, mycelial growth of *M. phaseolina* was strongly restricted by the strains of *P. fluorescens*. Mycelial growth inhibition was also observed with cell free siderophores. Clear inhibition zones ranging from 1.2 to 2 cm diameter were observed. Results of plate assay techniques showed that P_9 is more effective in suppressing the growth of *M. phaseolina* than P_7 (Table 1). The observations are in agreement with Singh and Arora (2001) demonstrated that *M. phaseolina* exudates contains chemical attractants that serve as signal for flagellar motility of *P. fluorescens*, motile *P. fluorescens* strains that may consume fungal exudates as nutrients and showed positive chemotoxis towards the attractants. This may be one of the mechanism involved in the antibiosis.

Table 1 ***In vitro* antibiosis of fluorescent pseudomonads against *Macrophomina phaseolina***

Treatment	Inhibition of mycelial growth (%)	Diameter of zone of inhibition by siderophores in mm	HCN production
P_7	62.5±1.15	38.6±1.76	++
P_9	80.0±0.58	52.3±1.45	+++

Each value is an average mean of three replicates.
± Indicates standard deviation
++ Indicates moderate; +++ Indicates strong eyanogenic potential

HCN production: The isolate P_9 produced maximum level of HCN whereas P_7 produced moderate level of HCN on low iron *Pseudomonas* agar for fluorescene media (Table 1). The antagonistic property of soil *Pseudomonads* against plant pathogenic fungi could be due to production of antibiotics, siderophores, ammonia, HCN, competition for nutrients or successful root colonization (Defago *et al.*, 1990). The strain P_9 was found to inhibit the growth of *M. phaseolina*, it can be assumed that the siderophores and HCN metabolites responsible for the fungal growth inhibition. There are reports that the biocontrol of pathogens through HCN production by certain fluorescent *Pseudomonads* may be due to the induction of plant resistance against certain pathogens (Viosard *et al.*, 1989).

Siderophore production: After 48 hr of incubation of the isolates, a parrot green colour in succinate medium and green colour in casamino acid medium developed is the positive indication of siderophore production. The cell free supernatant showing peak at 405 nm and 408 nm for P_9 and P_7, respectively is characteristic for bydroxamate type of siderophore. Fluorescent *Pseudomonads* have been widely used for the management of plant diseases (Schwyn and Neilands, 1987; O' Sullivan and O' Gara, 1992; Vidyasekharan *et al.*, 1997). They have suggested a probable mechanism of siderophore - mediated suppression of plant pathogen. According to our study, the siderophores and the culture of fluorescent *Pseudomonas* play an important and active role in disease suppression and growth promotion of plants against *M. phaseolina* (Table 1).

Pot culture assay: In the pot culture assay, *Pseudomonas* strain (P_9) were found to exert positive effect followed by P_7 on plant biomass, per cent seed germination and reduced disease incidence (Table 2).

Table 2 Antagonistic effect of *Pseudomonas fluorescens* on *Macrophomina phaseolina* under green house conditions

Treatment	Seed germination (%)	Disease incidence (%)	Root length (cm)	Shoot length (cm)	Root dry weight (mg)	Shoot dry weight (g)
M. Phaseolina	42.6±1.5	97.3±1.8	7.6±0.4	35.4±0.8	580±34.6	1.4±0.6
P7+*M.phaseolina*	92.3±1.2	45.4±2.4	12.1±0.5	45.5±0.4	865.7±14.4	1.9±0.1
P9+*M.phaseolina*	97.7±1.5	35.7±2.3	14.3±0.9	48.4±0.9	993.3±17.6	2.2±0.1

Field experiments: The effective *Pseudomonas* isolates which showed high degree of *in vitro* antagonism (P_7 and P_9) were studied for their *in vivo* antagonistic activity against *M. phaseolina* in field experiment (Table 3). In control plots where non-bacterised seeds were sown, mortality due to root rot caused by *M. phaseolina* by 56.6% and 46.7%, respectively.

Table 3 Evaluation of the efficacy of *Pseudomonas fluorescens* (P_7 and P_9) by seed treatment against *Macrophomina phaseolina* under field conditions

Treatment	Disease incidence (%)	Pod yield (kg/ha)	Seed germination (%)
Seed treatment with P_7	56.6±3.9	1021±3.8	84.0±0.9
Seed treatment with P_9	46.7±0.9	1460±4.8	97.0±1.5
Control (untreated)	72.0±1.2	830±5.4	62.0±1.2

Our results suggest that by inoculation with efficient strains of *P. fluorescens*, the root rot pathogen of groundnut i.e., *M. phaseolina* can be managed. These results are supported by the inhibition of mycelial growth of the pathogen by the siderophores and *P. fluorescens*. It is further strengthened by the green house and field experiments where 80% of bacteria inoculated plants were protected from *M. phaseolina* (Meena *et al.*, 2000). The development of commercial formulation of potential *Pseudomonas* fluorescens isolate (P_9) is under process.

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Short communication

Inheritance of seed yield and some quantitative traits in mustard, *Brassica juncea* (L.) Czern & Coss

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The mustard is an important edible oilseed crop of the country, grown during *rabi* season. Mustard yields are very low (884 kg/ha) in India compared to other countries (3657 kg/ha in Germany). Therefore, there is an urgent need to augment its productivity levels through the development of high yielding varieties. For this purpose, a plant breeder must possesses an adequate knowledge to decide which course of action to take in deciding the next generation. Hence present study was under taken to understand the *nature of gene effects involved in the inheritance of* various quantitative traits in mustard.

The experimental materials comprised of parents (P_1 and P_2), their F_1, F_2, B_1 ($F_1 \times P_1$) and B_2 ($F_1 \times P_2$) generations of four single crosses designated as "RSK 85 x GM 1", "RSK 85 x GM 2", "DIRM 52 x GM 1"and "DIRM 52 x GM 2" of mustard. These single crosses were affected at Main Castor and Mustard Research Station, GAU., S.K. Nagar during *rabi* 2004-05. The experiment was laid out in a Randomized Block Design with three replications. The distance between and within rows was 45 cm and 15 cm, respectively. Each replication consisted of single row of five meter length for parents and F_1 and ten rows of five meter length for each F_2 and back crosses. Five competitive plants from each parent, F_1 and 100 plants from each F_2 and backcross generations were randomly selected and observations were recorded on seed yield/plant (g), plant height (cm), branches/plant, oil *content (%) and 1000-seed weight (g). The data were* statistically analyzed and gene effects were estimated through the method suggested by Hayman (1958).

Above mentioned four crosses were carried out with a view to under stand the gene effects involved in the expression of seed yield and its component traits. The genetic control for the traits varied from cross to cross and trait-to-trait (Table 1).

Table 1 Estimates of additive, dominance and interaction parameters for five traits in mustard

Character	Cross	d	h	l	j	l	Type of epistasis
Number of branches/plant	RSK 85 x GM 1	0.46	2.58	2.66	1.52	1.23	Complementary
	RSK 85 x GM 2	-1.67	-9.87**	-8.13**	0.83	11.33**	Duplicate
	DIRM 52 x GM 1	-1.00	20.85**	20.13**	0.64	-22.50	Duplicate
	DIRM 52 x GM 2	-0.13	18.28	11.73*	-1.85	1.17	Complementary
Plant height	RSK 85 x GM 1	6.63	-46.63	-42.20	2.73	28.87	Duplicate
	RSK 85 x GM 2	-7.20*	-2.38	-5.47	-9.15*	-28.43	Duplicate
	DIRM 52 x GM 1	-12.23**	35.58	28.26	-18.25**	8.70	Complementary
	DIRM 52 x GM 2	0.53	37.30	52.26	6.09	-85.53	Duplicate
1000-seed weight	RSK 85 x GM 1	0.96**	-3.69**	-2.48**	1.29**	0.59*	Duplicate
	RSK 85 x GM 2	0.64*	0.84	1.24	0.66*	-3.52*	Duplicate
	DIRM 52 x GM 1	0.25**	-3.99**	-2.98**	8.69**	3.18**	Duplicate
	DIRM 52 x GM 2	-0.08**	-1.67**	-1.18**	0.52**	0.22**	Duplicate
Oil content	RSK 85 x GM 1	1.36**	0.28	1.72**	1.58**	3.20**	Complementary
	RSK 85 x GM 2	-0.45	4.43**	1.86	0.14	-0.55	Duplicate
	DIRM 52 x GM 1	7.42	-19.37	-19.70	-7.20	34.94	Duplicate
	DIRM 52 x GM 2	1.41**	-1.41**	-1.22**	-0.26**	-4.58**	Complementary
Seed yield/plant	RSK 85 x GM 1	19.17**	15.49	21.66	23.01**	-6.32**	Duplicate
	RSK 85 x GM 2	-4.30	1.50	-6.00	-1.83	-23.00	Duplicate
	DIRM 52 x GM 1	-0.83	0.99	-5.67	-0.50	-0.67	Duplicate
	DIRM 52 x GM 2	-6.00	-0. 99	2.67	-5.00	-56.67*	Complementary

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

It is clear that number of branches/plant is under the control of dominant gene effects with duplicate type of epistatic effect in cross "DIRM 52 x GM 1" and also in the cross "RSK 85 x GM 2" with opposite direction. Additive gene effects were found to be for inheritance of plant height in the negative direction in above both the crosses. As far as 1000-seed weight is concerned additive gene effect was more pronounced in the crosses *viz.*, "RSK 8S x GM1" "RSK 85 x GM 2" and "DIRM 52 x GM 1" with duplicate type of non-allelic gene interactions. The trait like oil content is completely inherited by the additive type of gene effects with complementary type for the crosses "RSK 85 x GM 1"and "DIRM 52 x GM 2".

For seed yield the cross "RSK 85 x GM 1" expressed significant additive effect with interaction of *j* and *l* type of duplicate gene effects. Similar results were also reported by Chauhan and Singh (1979), Yadava *et al.* (1981) and Yadav *et al.* (1993).

Both fixable and non fixable (non-additive) gene effect were important for the expression of plant height and number of branches/plant in the crosses like "DIRM 52 x GM 1" and "RSK 85 x GM 2". However, dominance was predominant in above both the crosses for the trait number of branches/plant and additive gene effect was more for plant height in negative direction. Similar results were reported by Yadav *et al.* (2005). So that, reciprocal recurrent selection would be more effective when both type of gene effects are controlling the traits.

It can be concluded that, yield attributing components like number of branches/plant was controlled by dominant gene effect. On the contrary to this, 1000-seed weight and oil content were controlled by additive gene effect, seed yield was also controlled by additive and epistatic gene interactions. Additive gene effect and non-allelic gene effects were found to play an important role in the inheritance of 1000-seed weight, oil content and seed yield/plant in cross "RSK 85 x GM 1". Therefore, simple recurrent selection or biparental mating may be effective for selecting the genotypes having the bolder seed size and high seed yield and oil content.

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Short communication

Genetic variability in sunflower (*Helianthus annuus* L.) genotypes

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Sunflower (*Helianthus annuus* L.) is an important oilseed crop cultivated for its premier oil with manifold uses. Genetic variability is the most important feature of any population and variability present in the population is the prerequisite in response to selection for any crop improvement programme. Selection of superior varieties will be possible only when adequate variability exists in the gene pool. Hence, the insight into the magnitude of variability present in a gene pool of a crop species is of utmost importance to plant breeder for starting a judicious plant breeding programme. The coefficient of variation expressed in phenotypic and genotypic levels are used to compare the variability observed among different characters. A wide range of variation has been reported for seed yield and seed number (Velkov, 1980) and other important components of yield (Virupakshappa and Sindagi, 1988). The heritability estimates aid in determining the relative amount of heritable portion in variation and thus help the plant breeder in selecting the elite inbreds from a diverse population. Therefore, the present study was undertaken for assessing the extent of genetic variability, heritability and genetic advance in sunflower germplasm lines.

The material for the present study comprised of 60 sunflower genotypes including 32 inbred lines, 22 populations and six checks obtained from Directorate of Oilseeds Research, Hyderabad. The experiment was conducted at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi*/summer 2005-06. Each genotype was sown in three rows of 5 m row length each with a spacing of 60 x 30 cm. in Randomized Block Design with three replications. Under each treatment and in each replication, ten plants were randomly selected and the observations were recorded on seed yield and its component characters *viz.*, days to 50% flowering, days to maturity, plant height, number of leaves/plant, head diameter, number of filled seeds, number of unfilled seeds, test weight and oil per cent. Analysis of variance and estimates of genotypic and phenotypic coefficients of variation, broad sense heritability and expected genetic gain were worked out following conventional methods (Falconer, 1981).

The analysis of variance revealed significant differences for all the ten traits studied (Table 1). The range of variation was maximum for the characters *viz.*, number of filled seeds/head (385.52 to 770.47) followed by number of unfilled seeds/head (104.93 to 316.65) and plant height (101.53 to 212.86 cm), while it was lowest in the case of test weight (3.69 to 7.17) (Table 2). In general, PCV values were marginally higher than GCV values. The characters studied in the present investigation showed moderate to low PCV and GCV values. The magnitude of variation was maximum for the characters seed yield, number of filled seeds, number of unfilled seeds and test weight. These results are in accordance with the results of Patil *et al.* (1996) and Sujatha *et al.* (2002), Fatima Sultana *et al.* (2005). Moderate levels of PCV and GCV were obtained for the plant height, number of leaves per plant and head diameter. These results are in agreement with the report by Sujatha *et al.* (2002). However, low values were obtained for days to 50% flowering, days to maturity and oil content. Similar results were obtained by Rao *et al.* (2003), Sujatha *et al.* (2002).

Table 1 ANOVA for seed yield and yield attributes in sunflower

Character	Mean sum of squares		
	Replications	Treatments	Error
Plant height (cm)	139.67	1458.06**	142.77
Number of leaves/plant	11.57	16.65**	7.73
Days to 50% flowering	0.51	25.18**	1.01
Days to maturity	0.13	23.85**	0.86
Head diameter (cm)	0.33	7.72**	0.17
Number of filled seeds	12592.53	17865.63**	4119.75
Number of unfilled seeds	4599.67	5487.92**	2478.95
Test weight (g)	0.05	1.74**	0.03
Oil content (%)	1.51*	22.36**	0.46
Seed yield	11.45	97.25**	8.61

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

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

Character	Range		Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability broad sense (h^2)	Genetic advance	GA as per cent mean
	Min.	Max.							
Plant height (cm)	101.53	212.86	581.20	438.43	14.84	12.89	75.43	37.46	23.06
Number of leaves/plant	22.16	34.94	10.70	2.97	11.04	5.82	27.75	1.87	6.32
Days to 50% flowering	54.33	67.67	9.07	8.06	4.84	4.56	88.86	5.51	8.86
Days to maturity	84.67	98.33	8.52	7.66	3.16	2.99	89.90	5.41	5.85
Head diameter (cm)	13.73	21.50	2.69	2.52	10.05	9.72	93.68	3.16	19.38
Number of filled seeds	385.52	770.47	8701.71	4581.96	19.07	13.84	52.65	101.19	20.68
Number of unfilled seeds	104.93	316.65	3481.94	1002.99	26.46	14.20	28.80	35.01	15.70
Test weight (g)	3.62	7.17	0.60	0.57	16.18	15.79	95.00	1.52	31.75
Oil content (%)	34.85	47.08	7.76	7.30	6.90	6.70	94.07	5.40	13.39
Seed yield (g)	15.67	42.11	38.16	29.55	26.39	23.22	77.43	9.85	42.09

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

However, high variance values alone are not the determining factors of the expected progress that could be made in respect of quantitative traits (Falconer, 1981). It was suggested that the GCV together with the high h_2 estimates would give a better picture of the extent of genetic gain to be expected under selection.

In the present investigation, all the characters expressed high heritability estimates ranging from 27.75 to 95.00 percent. The highest heritability was recorded by test weight (95.00%) followed by oil content (94.07%) and head diameter (93.68%). The genetic advance was highest for number of filled seeds per head (101.19) followed by plant height (37.46) and number of unfilled seeds/head (35.01). While, the genetic advance as percent of mean was highest for seed yield (42.09%) followed by test weight (31.75%), plant height (23.06%), number of filled seeds/head (20.68%) and head diameter (19.38%) and rest of the characters recorded medium to low genetic advance as percent of mean. The variability and genetic advance as percent of mean was higher for the characters *viz.*, number of filled seeds/head, seed yield/plant, number of unfilled seeds/head, test weight and plant height. While, high heritability coupled with high genetic advance as percent of mean was noticed for the characters *viz.*, test weight, seed yield/plant, number of filled seeds/head and plant height suggesting the presence of additive gene action controlling these traits. Similar results were reported by Patil *et al.*, (1996) and Sujatha *et al.*, (2002), where heritability is high and genetic advance as percent of mean is low, the environment influenced these traits. The expression of traits is unstable, hence, breeder should not rely on the estimates of heritability alone.

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Short communication

Autogamy in sunflower (*Helianthus annuus* L.) genotypes

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Sunflower is a highly cross-pollinated crop. Generally cross pollination takes place through insects, particularly bees. To over come the higher degree of self-incompatibility, adequate pollination by other means has to be taken up and to overcome the problem of poor seed set there is a need to develop suitable varieties and hybrids with higher degree of self fertility.

Realizing the importance of self-compatibility in sunflower, it is essential to have a comprehensive study to identify high autogamous lines with high seed oil and high yield (Ivanov, 1975). Keeping in view the above problem, the present investigation was undertaken to evaluate the newly developed inbreds of the Directorate of Oilseeds Research along with populations and hybrids.

Sixty sunflower genotypes including inbred lines, populations and hybrids were evaluated in Randomized Block Design at College of Agriculture, Hyderabad during *rabi*/summer 2005-06. Each genotype was sown in three rows of 5 m length with a spacing of 60 x 30 cm and replicated thrice. Under each treatment and in each replication, 15 plants were randomly selected for 3 operations, out of which five plants were covered with cloth bag soon after the appearance of ray florets and were not disturbed till maturity to study autogamy per cent, another five plants were covered with cloth bag and hand pollination was done by gently rubbing the heads with hand without removing bags to study the geitonogamy and the other five plants were left for open pollination. Seed set percentage, autogamy and geitonogamy were calculated as per George and Shein (1980).

The data was recorded on number of filled seeds/head, number of unfilled seeds/head and seed yield in the heads covered with cloth bags, those covered with cloth bags and hand pollinated, and open pollinated. Seed set per cent, autogamy and self-compatibility were calculated as shown below :

$$\text{Seed set (\%)} = \frac{\text{Number of filled seeds under open pollination}}{\text{Total number of seeds under open pollination (Filled seeds + unfilled seeds)}} \times 100$$

$$\text{Seed set under autogamous condition} = \frac{\text{Number of filled seeds under self pollination}}{\text{Total number of seeds under self pollination}} \times 100$$

$$\text{Seed set under geitonogamous condition} = \frac{\text{Number of filled seeds under bagging with hand pollination}}{\text{Total number of seeds under bagging with hand pollination}} \times 100$$

$$\text{Autogamy (\%)} = \frac{\text{Seed set under self pollination}}{\text{Seed set under open pollination}} \times 100$$

$$\text{Geitonogamy (\%)} = \frac{\text{Seed set under bagging with hand pollination}}{\text{Seed set under open pollination}} \times 100$$

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Table 1 Seed set per cent, autogamy, geitonogamy under different conditions

Genotype	Seed set per cent			Autogamy	Geitonogamy
	SP	HP	OP		
ARM-238	60.13	66.90	75.03	80.13	89.17
ARM-239	58.54	63.66	71.22	82.20	89.38
ARM-240	58.99	62.38	70.89	83.21	87.99
ARM-242	51.15	53.97	65.72	77.83	82.13
ARM-243	49.66	59.60	70.06	70.87	85.07
ARM-245	53.82	58.49	71.25	75.53	82.09
ARM-247	47.52	57.98	69.05	68.82	83.97
ARM-250	54.14	70.65	78.77	68.72	89.69
GP-322-1	49.18	59.77	67.61	72.74	88.39
GP-322-2	60.69	70.11	70.06	72.35	100.07
GP-325-3	46.08	47.20	65.37	70.49	72.20
GP-1334-3	46.43	59.44	63.45	73.17	93.67
GP-2158-4	49.67	59.18	63.67	52.31	92.95
GP1-2086	48.22	60.14	64.37	74.91	93.44
GP1-69	47.73	55.85	60.22	79.25	92.73
GP2-1746	50.65	54.38	69.68	72.69	78.04
GP2-2035	46.38	57.04	74.80	62.00	76.25
GP9-33F-4-2	34.25	59.52	63.77	95.07	109.02
GP9-38C-2-1	45.42	55.00	67.80	56.99	81.12
GP9-162-1-3	53.66	58.19	63.65	84.31	91.43
GP9-217-4-4	47.54	62.07	66.61	71.38	93.19
GP9-279-7-4	48.47	52.32	56.71	85.48	92.27
GP9-290-5-3	42.65	51.81	64.83	65.79	79.92
GP9-472-4-1	45.44	54.72	62.75	72.42	87.20
GP9-472-5-5	39.27	49.99	60.07	65.38	83.22
GP9-472-7-1	47.00	52.44	60.42	77.80	86.79
GP9-472-7-2	51.60	59.00	70.01	73.71	84.28
GP9-472-7-4	48.19	57.41	66.06	72.95	86.91
GP9-472-7-5	55.78	63.39	80.53	69.27	78.73
GP9-515-7-3	56.97	55.57	72.91	78.13	76.21
GP9-846-4-4	46.54	54.26	60.50	76.92	89.68
RHA6D1	47.91	58.87	68.38	70.06	86.09
Mean of inbreds	**49.73**	**58.47**	**67.35**	**73.96**	**87.01**
DRSF-104	54.83	54.72	65.46	83.76	83.59
DRSF-110	50.46	58.31	71.66	70.42	81.37
DRSF-113	54.63	59.72	73.95	73.87	80.76
DRSF-114	50.19	59.49	69.89	71.81	85.12
DRSF-115	47.26	52.87	70.17	67.36	75.34
DRSF-116	47.32	55.89	71.62	66.07	78.04
DRSF-118	44.76	53.58	70.99	63.05	75.48
DRSF-119	64.15	77.36	84.54	75.88	91.51
REC-422	54.13	65.60	69.34	78.05	94.60
REC-428	50.25	54.34	58.76	85.51	92.48
REC-431	51.69	56.21	65.29	79.16	86.10
REC-433	45.34	48.92	58.89	76.99	83.08

Genotype	Seed set per cent			Autogamy	Geitonogamy
	SP	HP	OP		
REC-435	43.77	47.98	60.69	72.11	79.06
REC-441	44.78	61.77	73.15	61.22	84.45
REC-443	39.14	50.19	55.67	70.30	90.16
REC-446	44.69	53.89	56.85	78.61	94.80
REC-448	45.59	51.62	62.51	72.93	82 58
R.S.Boardagen-1	52.36	62.95	80.23	65.26	78.46
R.S.Boardagen-2	45.39	63.32	70.34	64.53	90.02
R.S. Master	50.54	57.55	69.89	72.31	82.34
R.S. Sartov	50.30	58.71	66.68	75.43	88.05
R.S. Spec	48.05	57.46	69.19	69.45	83.05
Mean of populations	**49.19**	**57.56**	**68.74**	**71.94**	**84.02**
DRSF-108	51.67	61.51	85.30	60.57	72.11
TNAUSUF-7	48.21	53.97	66.98	71.97	80.57
Gausuf-15	56.03	65.37	73.30	76.44	89.18
KBSH-1	58.71	66.36	73.79	79.56	89.93
Morden	48.37	56.93	85.48	56.59	66.60
KBSH-44	62.01	69.18	75.91	81.69	91.13
Mean of checks	**54.16**	**62.22**	**76.79**	**71.13**	**81.58**
General mean	**49.90**	**58.45**	**68.55**	**73.05**	**85.54**
SEm±	0.40	0.33	0.35	0.30	0.29
CD(P=0.05)	1.14	0.92	0.98	0.85	0.83
CV (%)	1.41	9.82	8.86	7.02	6.03

SP = Self-pollination (Bagging); HP = Bagging with hand pollination; OP = Open pollination

Perusal of results revealed that seed set was highest under open pollination followed by hand pollination and self-pollination. According to Seetharam, 1982, seed set under open pollination recorded significant difference over other pollination methods and it is determined to a large extent by the population of pollinators in the vicinity of the crop. This might be due to pollen movement effected by insect pollinators. The lowest seed set under self-pollination was mainly due to lack of pollen transfer to the stigmatic surface and self-incompatibility nature. Considering the mean per cent seed set across pollination methods and genotypes, hybrids registered relatively higher seed set followed by inbreds and populations. This could be due to compatible alleles in the hybrid compared to inbreds. Genotypes, ARM-238, DRSF-119 and KBSH-44 under self pollination, ARM-250, DRSF-119 and KBSH-44 under hand pollination and under open pollination, GP9-472-7-5, and Morden recorded higher seed set per cent.

Autogamy per cent was higher in hybrids followed by inbred lines and populations. Similar results were reported by earlier workers (Sumangala and Giriraj, 2002). According to Miller and Fick (1997) the degree of self-incompatibility and self fertility depends on three conditions, *viz.*, genetic control, environment and morphology of floral structures. In the present study genotypic differences influenced degree of autogamy in the genotypes studied.

Hybrid, KBSH-1, inbreds, GP9-279-7-4, GP9-33E-4-2 and GP9-162-1-3 and populations, REC-428 recorded higher autogamy percentage. Therefore, it is necessary for development of self-fertile populations or hybrids to alleviate the dependency on bees for good seed set (Roath and Miller, 1982). Selection for self fertility enables to accumulate self compatible genes in germplasm lines (Sumangala and Giriraj, 2002).

A genotype is considered as self-fertile if it sets seed under bagging, George (1982) pointed out that this procedure does not ensure potential self-pollination in some genotypes which, however, can be achieved by manual self-pollination, therefore, the latter method should be included in self-compatibility studies. Hence, they estimated self-compatibility as the ratio between seed set under manual self-pollination and open pollination. In the present study, estimates of self-compatibility of genotypes (Table 1) revealed some interesting facts. The genotypes with low autogamy recorded higher self-compatibility. Thus, autogamy does not reflect self-compatibility. George (1982) also obtained similar results. It is also evident that even an incompatible genotype can exhibit higher self-compatibility under induced pollination. As reported earlier, self-pollination in the covered heads was ensured in this study by hand pollination eight times uniformly

during peak flowering to ensure that all the florets in the capitulum had equal opportunity to receive pollen for fertilization. The possible reason might be high self-fertility coupled with timely supplemented pollen for more than100% self compatibility recorded in some of the genotype. In these genotypes, the seed set was higher sunder bagging + hand pollination than under open-pollination. The seed set under open pollination is mainly determined by the activity of insect pollinators, particularly honey bees.

The hybrids recorded higher self compatibility followed by inbreds across the pollination methods. Similar results were earlier reported by Rathod *et al.* (2003). Between the two pollination methods, cloth bags with assisted pollination recorded higher self-compatibility compared to cloth bag suggesting higher compatibility reaction of pollen when assisted by manually. Hence, in sunflower breeding programmes, greater emphasis should be laid on evaluating the genotypes for self-compatibility. For the development of inbreds highly self-compatible lines with uniform plant height and flowering, high seed yield and oil content should be utilized. This may further enable us to accumulate self-compatible genes in the inbred lines. In heterosis breeding also, it is desirable to evaluate the inbred lines for self-compatibility, as it ultimately influences self-compatibility in the hybrids as well.

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Short communication

Heterosis in relation to combining ability for seed yield and its contributing traits in sesame, *Sesamum indicum* L.

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Sesame, *Sesamum indicum* L. is an important oilseed crop with 40-54% oil and 20-25% protein. The productivity of the sesame in Maharashtra is very low i.e., 220 kg/ha and the situation is similar in the country. To enhance the present yields and overcome the stagnation, it is essential to reshuffle the genes through hybridization. Hence, it is necessary to identify the gene action involved in the expression of various yield contributing characters and also the combining ability of the parents and the resulting crosses. The present study was, therefore, undertaken to estimate heterosis in relation to combining ability effects for seed yield and its related traits.

Twelve female parents, *viz.*, JLT-7, JLT-26, Punjab Til-1, RT-125 , Uma , GT-2 , Goppya, RT-103, YLM-11,YLM-17, Rajeshwari and TMV-6 were crossed with eight male parents *viz.*, NIC-7829, NIC-7941, NIC-8316, SI-32, RJS-17, Keriya-7, BDN local and RT-46 in a line x tester mating design during *rabi*, 2003. The resultant 96 hybrids were advanced to obtain F_2s keeping a portion of the seed of F_1s for next season. The generated materials *viz.*, 96 F_1, 96 F_2 and their parents were planted in Randomized Block Design with three replications during *kharif*, 2004. In each replication, the parents and F_1s were raised in single row and F_2s in seven row of 3.5 meter length. The rows and plants were spaced at a distance of 45 cm and 15 cm, respectively. Phule Til-1 was used as standard check. Normal agronomic practices applicable to the commercial crop of sesame were adopted. Observations were recorded on five plants in parents and F_1s and 20 plant in F_2s in each replication on yield and its components. Oil content in seed was determined by NMR method. The mean values for each character were taken to estimate combining ability based on line x tester model described by Kempthorne, (1957). Standard heterosis and inbreeding depression were estimated as per standard procedures.

Analysis of variances (Table 1) revealed significant differences among the parents and hybrids for all the characters in both the generation indicating the presence of genetic variability in the material under study.

Table 1 Analysis of variance for combining ability

Source of variation	d.f.	Day to maturity	Plant height	No. of branches	No. of capsules/plant	Capsules length	No of seeds/ capsule	Test weight	Oil content	Harvest Index	Seed yield/ plant
Parents	19	64.18**	572.09**	0.58**	137.06**	0.11**	87.96**	0.07**	4.73**	109.09**	2.03**
Hybrids	$96F_1$	34.24**	450.35**	1.32**	410.41**	0.08**	104.78**	0.09**	2.51**	70.63**	11.03**
	$96F_2$	45.82**	489.89**	0.67**	386.40**	.08**	215.81**	0.08**	2.17**	51.54**	9.73**
Parents vs Hybrids	F_1	28.82**	4938.17**	0.24	5617.26**	0.96**	1470.3**	0.89**	11.99**	255.59**	124.39**
	F_2	207.4**	3378.68**	16.93**	2124.86**	0.77**	114.2	0.07	44.45**	122.0**	68.65**
Lines	F_1	172.84**	2486.32**	5.798**	1166.33**	0.23**	335.78**	0.12	4.66**	342.67**	39.37**
	F_2	271.7**	1980.88**	1.03	943.38**	0.08	394.27**	0.11	9.06**	124.23**	32.08**
Testers	F_1	115.14**	197.37	2.01**	1123.59**	0.23**	93.94	0.21**	2.03	108.35**	35.18**
	F_2	26.38**	316.07	0.89	1148.97**	0.14	315.16	0.11	2.61**	28.85	34.02**
Lines x testers	F_1	7.08**	182.50*	0.62**	237.59**	0.05**	72.77**	0.08**	2.24**	28.34**	4.79**
	F_2	15.32**	292.62**	0.59**	237.51**	0.08**	181.28**	0.07**	1.15**	43.22**	4.34**
Errors	F_1	1.84	9.63	0.15	32.90	0.01	26.82	0.04	0.69	14.46	0.37
	F_2	2.80	75.70	0.45	35.64	0.02	44.04	0.05	0.28	5.92	0.22
62 *gca*	F_1	4.56**	38.64**	0.11**	30.24**	0.01*	4.44**	0.01***	0.04*	6.57**	1.08**
	F_2	4.45**	28.52**	0.01**	26.95**	0.01**	5.78**	0.01*	0.16	1.11**	0.96*
62 *sca*	F_1	1.56**	57.62**	0.16**	68.23**	0.01**	15.32	0.01**	0.62*	4.63**	1.47**
	F_2	4.17**	72.32**	0.05	67.29**	0.02**	45.74**	0.001	0.29**	12.43**	1.37**

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

Table 2 General combining ability effects of parents in sesame

Source of variation	Genera-tion	Days to Maturity	Plant height	No of branches/ plant	No .of capsules/ plant	Capsule length	No of seeds/ capsule	Test weight	Oil content	Harvest index	Seeds yield
LINES											
JLT-07	F_1	-2.205 **	7.377 **	0.566 **	5.357 **	0.027	5.576 **	-0.018	0.022	1.066	1.535 **
	F_2	-4.385 **	-8.337 **	-0.154	5.323 **	0.084 **	5.122 **	0.078	0.392 **	2.726 **	1.322 **
JLT-26	F_1	-2.663 **	-0.832	0.303 **	11.407 **	0.056 **	4.497 **	0.090 *	0.425 *	4.735 **	1.926 **
	F_2	-2.177 **	0.221	0.13	11.077 **	-0.024	2.167	0.088 *	0.191	2.459 **	1.830 **
PunjabTil-1	F_1	0.003	-2.382 **	0.583 **	8.541 **	0.027	2.455 *	0.051	-0.719 **	3.917 **	1.226 **
	F_2	-0.719 *	-4.820 **	0.209	4.377 **	0.059 *	4.976 **	0.068	0.576 **	1.290 *	1.472 **
RT-125	F_1	-1.997 **	-12.557 **	0.328 **	-1.093	-0.090 **	-0.699	0.003	0.283	1.233	0.243
	F_2	-3.469 **	-5.050 **	-0.045	5.802 **	-0.024	0.926	-0.029	0.248 *	1.534 **	0.659 **
Uma	F_1	3.295 **	2.160 **	0.774 **	10.295 **	0.094 **	3.989 **	-0.009	-0.626 **	1.792 *	1.668 **
	F_2	2.531 **	3.613 *	0.175	5.964 **	0.03	-0.228	-0.053	-1.562 **	-0.893	1.026 **
GT-2	F_1	-1.872 **	-15.340 **	-0.463 **	-5.147 **	-0.110 **	-4.999 **	-0.001	0.094	1.527	-0.736 **
	F_2	-1.344 **	-9.062 **	-0.241	-9.748 **	-0.111 **	-2.962 *	-0.053	0.361 **	0.031	-1.032 **
GOPPYA	F_1	-2.413 **	-10.494 **	-0.742 **	-5.759 **	0.160 **	-2.274 *	-0.165 *	0.309	-0.303	-1.378 **
	F_2	-3.177 **	-13.725 **	-0.375 **	-2.782 *	-0.036	-4.570 **	-0.051	0.06	-1.031 *	-0.861 **
RT-103	F_1	-1.080 **	-6.215 **	-0.251 **	-5.097 **	0.056 **	0.901	0.047	0.578 **	0.735	-0.982 *
	F_2	-1.635 **	0.988	0.042	4.161 **	0.043	0.692	0.091 *	0.696 **	-1.675 *	-0.807 *
YLM-11	F_1	-0.705 *	1.473 *	-0.201 *	-0.443	-0.102 **	-4.911 **	-0.013	0.213	0.397	-0.503 *
	F_2	0.990 **	7.063 **	0.321 *	-4.136 **	0.039	3.276 *	-0.05	-0.022	1.773 **	-1.011 *
YLM-17	F_1	2.170 **	6.810 **	-0.188 *	-5.447 **	-0.040 *	1.922	-0.094 *	0.221	-1.044	-0.357 *
	F_2	2.531 **	0.975	-0.137	1.515	0.039	1.372	-0.027	0.028	1.414 **	-0.524 *
RAJESHWARI	F_1	1.628 **	10.885 **	-0.217 **	-6.834 **	0.081 **	-3.745 **	0.039	-0.162	-4.740 **	-0.899 *
	F_2	6.031 **	8.659 **	0.163	5.957 **	-0.045	-8.803 **	0.043	-0.627 **	-4.337 **	-0.882 *
TMV-6	F_1	5.837 **	19.114 **	-0.492 **	-5.780 **	-0.160 **	-2.711 *	0.07	-0.638 **	-9.314 **	-1.744 *
	F_2	4.823 **	19.475 **	-0.087	-4.244 **	-0.053	-1.966	-0.061	-0.341 **	-3.291 **	-1.191 **
SE+	F_1	0.277	0.633	0.081	1.171	0.016	1.057	0.043	0.170	0.776	0.124
	F_2	0.342	1.776	0.138	1.219	0.029	1.355	0.044	0.104	0.497	0.095
CD(5%)	F_1	0.547	1.250	0.159	2.310	0.031	2.085	0.085	0.336	1.531	0.244
	F_2	0.675	3.503	0.271	2.404	0.057	2.672	0.086	0.204	0.980	0.187
CD(1%)	F_1	0.721	1.648	0.210	3.047	0.041	2.751	0.111	0.443	2.020	0.322
	F_2	0.890	4.621	0.358	3.171	0.076	3.525	0.114	0.270	1.293	0.246
TESTERS											
NIC-7829	F_1	-2.260 **	-1.169 **	0.110 **	-0.154	-0.092 **	-1.639 **	-0.100 *	-0.111	1.696 **	0.311 *
	F_2	-0.483 **	-0.698	0.053	0.457	0.014	1.510 *	-0.041	-0.613 **	0.333	0.501 **
NIC7941	F_1	-1.844 **	-2.955 **	0.272 **	7.149 **	0.005	2.344 **	-0.054 *	-0.308 **	1.471 **	1.253 **
	F_2	-0.26	-2.745 **	-0.1	4.777 **	0.039 **	1.983 **	-0.048 *	0.144 **	-0.404	0.787 **
NIC-8316	F_1	-0.066	-1.683 **	-0.126 **	-5.223 **	-0.098 **	-0.153	-0.098 *	0.055	-1.007 *	-0.658 **
	F_2	0.767 **	-1.357	0.05	-5.607 **	-0.053 **	-1.642 *	-0.092 *	0.105 *	-1.032 *	-1.043 **
SI-32	F_1	1.740 **	2.359 **	0.124 **	-0.793	0.01	-2.406 **	0.096 **	-0.216 *	-0.437	-0.144 *
	F_2	0.740 **	3.277 **	0.128	-1.962 **	-0.073 **	-0.951	0.068 **	0.180 **	-0.35	0.109 *
RJS-17	F_1	2.906 **	2.959 **	0.205 **	5.549 **	-0.034 **	0.477	0.061 **	0.1	0.76	0.572 **
	F_2	0.128	4.074 **	-0.1	7.191 **	-0.045 **	3.147 **	0.022	0.207 **	0.485	0.979 **
KERIYA-7	F_1	-0.483 **	2.495 **	-0.390 **	-8.657 **	0.147 **	0.611	0.054 *	0.133	-1.294 *	-1.700 **
	F_2	-0.26	1.524	0.261 **	-9.509 **	0.114 **	-4.809 **	0.011	-0.101	-0.968 *	-1.807 **
BDN Local	F_1	1.045 **	0.2	-0.273 **	-2.898 **	0.060 **	-0.917	0.059 **	0.447 **	-3.030 *	-0.664 **
	F_2	0.990 **	0.574	-0.247 **	-0.137	0.033 *	-2.631 **	0.052 *	-0.042	0.227	-0.155 **
RT-46	F_1	-1.038 **	-2.205 **	0.077	5.027 **	0.002	1.683 **	-0.019	-0.101	1.842 **	1.031 **
	F_2	-1.622 **	-4.648 **	-0.042	4.791 **	-0.028	3.394 **	0.028	0.119 *	1.710 **	0.629 **
SE+	F_1	0.226	0.517	0.066	0.956	0.013	0.863	0.035	0.139	0.634	0.101
	F_2	0.279	1.450	0.112	0.995	0.024	1.106	0.033	0.085	0.406	0.077
CD(5%)	F_1	0.446	1.020	0.130	1.886	0.026	1.703	0.069	0.274	1.250	0.199
	F_2	0.551	2.860	0.221	1.963	0.047	2.182	0.070	0.167	0.800	0.153
CD(1%)	F_1	0.589	1.346	0.171	2.488	0.034	2.246	0.091	0.361	1.649	0.263
	F_2	0.727	3.773	0.292	2.589	0.062	2.878	0.093	0.220	1.056	0.201

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

The interaction due to parents and hybrids was significant for all the characters except number of branches in F_1 and test weight and seeds/capsule in F_2 indicating high heterotic response in the material studied. The variances due to lines x testers (interaction) were highly significant for all the characters, there by showing their high specific combining ability (Karuppaiyan *et al.*, 2000). The mean sum of square due to *gca* and *sca* were significant for all characters except for number of branches/plant and test weight in F_2 indicating that both additive and non-additive gene actions were important for the characters studied. Similar results were reported by Krishnaiah *et al.* (2003). The estimate of component variance suggested that the variance due to *sca* was greater than the variance due to *gca* for plant height, number of branches/plant, number of capsules/plant, capsule length, number of seeds/capsule, test weight, oil content, harvest index and seed yield/plant in F_1 and F_2 indicating the non-additive gene action governing these traits. Present findings are in line with Ragiba and Reddy (2000). Equal importance of additive and non-additive with preponderance of additive effects were observed for days to maturity in F_1 and F_2. Hence

simple selection of progenies in segregating generation would result in rapid improvement for earliness (Karuppaiyan *et al.*, 2000).

The general combining effect revealed that none of the parents was a good general combiner for all the traits (Table 2). Therefore a multiple crossing programme involving these parents would offer good scope for improving the yield by combining the positive effects of most of the yield attributing characters. The estimate of *gca* effects of female parents in F_1 and F_2 generation for 10 characters revealed that Punjab Til-1 as best general combiner for number of capsules/plant, number of seed/capsule, harvest index and seed yield/plant, JLT-26 for days to maturity, number of capsules/plant, test weight, harvest index and seed yield/plant, where as male parent, RT-46 for days to maturity, number of capsules/plant, harvest index and seed yield/plant. A good degree of correspondence between *gca* effects in F_1 and F_2 generation indicated the possibilities of postponing combining ability studied to F_2 generation to obtain more reliable information, where the problem of producing sufficient quality of hybrid seed is evident (Ragiba and Reddy, 2000). In general, crosses with significant *gca* effects exhibited highly significant heterosis for most of the characters studied indicating that *sca* of crosses can be a suitable index to determine the performance of a crosses in the exploitation of heterosis.

Of the 96 F_1 and F_2 crosses studied for specific combining ability none of them exhibited significant and consistent *sca* effects for all the characters. However, for seed yield 28 crosses in F_1 and 35 crosses in F_2 exhibited significant specific combining ability effects. From practical point of view, the crosses, RT-125 x SI-32 ,YLM-17 x NIC-8316, Rajeshawari x NIC-7941 and RT-125 x RJS-17 exhibited significant specific combining ability effects in both generations along with desirable standard heterosis and low inbreeding depression (Table 3).

The present investigation suggested that the crosses, Rajeshwari x NIC-7941, RT-125 x RJS-17, Punjab Til-1 x RT-46 and JLT-26 x BDN Local may be selected both for commercial exploitation of heterosis. The parents of Punjab Til-1 x RT-46 were with high x high *gca* effects and significant *sca* effects in both the generation indicating the presence of additive x additive gene action (Karuppaiyan *et al.*, 2000). The parents of remaining crosses were with high x low or low x high *gca* effects with significant *sca* effects in both the generations indicating presence of additive x dominance gene interaction. Therefore, the above crosses could throw desirable transgressive segregates, where as the crosses, RT-125 x SI-32 and YLM-17x NIC-8316 exhibited significant *sca* effects in both the generations with desirable standard heterosis and low inbreeding depression. Hence these crosses can be selected exclusively for the commercial exploitation of heterosis in sesame (Singh, 2004).

Table 3 Ten best cross combinations based on gca, sca effects and standard heterosis and inbreeding depression in sesame

Crosses	*Per se* performance	*gca* effects P_1	*gca* effects P_2	*sca* effects F_1	*sca* effects F_2	Standard heterosis	Inbreeding depression	Traits for which crosses also exhibited desirable *sca* effects
RT 125 x SI 32	9.87	0.242	0.144*	2.724**	1.36**	96.16**	11.52**	Days to maturity (2.302**), Branches (0.73**), No of capsules (20.14**), Harvest index (5.00**), No of seed/capsules (10.23**)
YLM 17 x RT 46	9.93	-0.503	1.031	2.215**	-0.604*	97.48**	38.59**	Branches (0627**), capsules length (0.131*)
YLM 11 x RJS 17	9.10	0.503**	0.572**	1.986**	-0.533*	80.91**	33.74**	Harvest index (9.312**)
YLM 17 x NIC 8316	7.93	-0.357*	-0.658**	1.871**	1.668*	57.06**	15.19**	Days to maturity (2.274**), No of capsules (16.986**)
RT 103 x NIC 7829	8.23	-0.982**	0.311*	1.860**	0.241	63.68**	20.69**	Branches (1.256*)
Rajeshwari x NIC 7941	9.23	-0.899**	1.253**	1.835**	0.830**	83.56**	20.61**	No of capsules 913.868**)
RT 125 x RJS 17	9.63	0.243	0.572**	1.774**	0.863**	91.51**	5.53**	Plant height (2.37**), Branches (0.716**), Harvest index (6.256**), No of capsules (14.93**), Seeds/capsules (6026**)
Punjab Til 1 x RT 46	10.73	1.226**	1.031	1.432**	0.300	113.38**	16.15**	Plant height (6.156**), No of capsules (16.446**)
JLT 26 x BDN Local	9.67	1.926**	-1.700**	1.360**	0.992	92.19**	4.1	No of capsules (6.807**)
RT 103 x NIC 8316	6.73	0.982**	0.658**	1.329**	-0.243	37.86	33.17	Branches (1.256**)

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

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Short communication

Influence of sowing dates on thermal requirements, productivity and oil quality of Indian mustard, *Brassica juncea* (L.) Czern and Coss cultivars

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Temperature and day length influence growth, development and productivity of a crop through their effect on occurrence and length of different phonological stages of crop. Each crop needs a definite amount of growing degree days (GDD) or heat units (HU) and heliothermal units (HTU) for different phenophases during its life cycle. The concept of GDD or HU has been applied in sunflower (Singh and Gupta, 2002). Climatic variables and GDD and HTU resulted from shift in sowing dates modify phasic development, accumulation and partitioning of drymatter in *Brassicas* (Singh *et al.*, 1993). The present study was undertaken to generate information on thermal requirement of important Indian mustard cultivars.

The study was carried out at the Punjab Agricultural University, Ludhiana during *rabi*, 2005-06 under irrigated conditions on sandy loam soil of neutral pH (7.6). The soil tested low in organic carbon (0.36%), medium in available phosphorus (22.5 kg/ha) and rich in available potassium (240 kg/ha). The treatments were replicated thrice in Split Plot Design with 4 sowing dates (25 September, 10 and 25 October and 10 November) in the main plots and 4 genotypes (NRCDR 2, Varuna, Kranti and RL 1359) in the sub plots. Crop was fertilized with 50 kg N along with 30 kg P_2O_5/ha at sowing and additional dose of 50 kg N/ha after first irrigation at about one month after sowing. GDD or HU were computed as given below with threshold or base temperature of 5°C (Nanda *et al.*, 1996). Helio-thermal units (HTU), the product of GDD and the corresponding actual sunshine hours for that day were computed on daily basis. The GDD and HTU were accumulated from the date of sowing up to each individual phenological event to give accumulated GDD and HTU.

The days to flowering initiation and 100% flowering significantly increased with delay in sowing from 25 September to 10 November while that for maturity decreased up to 25 October except 100% flowering between 25 September and 10 October (Table 1). The GDD and HTU required for different phenophases (sowing to flowering initiation to 100% flowering to maturity) decreased significantly with each delay in sowing. Crop sown on early date accumulated more HU and HTU in shorter time due to higher temperature and more sunshine hours, which resulted in early flowering. Similar results were reported by Roy *et al.* (2005). Crop duration decreased with each delay in sowing due to high temperature towards maturity in the late sown crop.

The GDD required for flowering initiation to 100% flowering were similar in 10 October (104°C) and 25 October (101°C) sowing, but there were large differences in HTU (804 and 393 for respective sowing dates) indicating significance of HTU in phasic growth of plants, sink development and translocation of photo-assimilates from source to sink. Similarly, during 100% flowering to maturity stage, GDD and HTU in 25 October sowing were significantly lower than 10 October as well as 10 November sowing. Higher GDD and HTU requirement for 10 October sowing than 25 September sowing might be due to the fact that 25 September sown crop was harvested in last week of February whereas October sown crop lasted up to March and was exposed to higher temperature and sunshine hours.

There was consistent reduction in number of siliquae/plant, seeds/siliqua, 1000 seed weight and ultimately seed and stalk yields with each delay in sowing date (Table 2). Number of secondary branches, siliquae/plant and 1000 seed weight in 25 September and 10 October sowing and seeds/siliqua of 25 September sown crop were significantly higher than 10 November sowing. The highest seed and stalk yields were registered in 10 October sowing which were at par with 25 September sowing but reduced significantly with delay in sowing to 10 November. THU 10 October (2672 kg/ha) sowing resulted in 58.0 and 107.8% higher seed yield than 25 October and 10 November sowings respectively.

Yield improvement in early sowing dates accrued from longer period of reproductive phase (Table 1). In late sown crop, the duration of crop was reduced; reproductive phase was reduced more than the vegetative phase due to rise in temperature resulting in lesser time available for transport of photosynthates to sink ultimately leading to lower seed yield compared to early sowings. The present work corroborates the findings of Kar and Chakravarthy (1999) and Roy *et al.* (2005). Reduction in oil content with

delay in sowing from 25 September (38.0%) to 25 October (35.3%) was significant. Earlier, Ghosh and Chatterjee (1988) reported similar reduction in oil content with delayed sowing. Hocking *et al.* (1997) reported 2.7% reduction in oil content for each degree rise in temperature during seed filling. Increase in temperature from flowering to maturity causes flower abortion, hastened maturity, poor seed development, lesser accumulation and poor quality of oil.

The influence of sowing dates was discernible on palmitic, linoleic and linolenic acids (Table 3). Crop sown on 25 September resulted in lower linoleic acid but higher linolenic acid content in seeds compared to 10 and 25 October and 10 November sowings which were at par with each other. Temperature variations at which crops are grown decisively influence the production and utilization of biochemical compounds. Longer reproductive phase and cooler temperatures during seed development stage are favourable for higher seed yield and good quality oil (Pritchard *et al.*, 2000). The process of seed development and oil synthesis in early sowing dates took place in comparatively cool conditions leading to formation of long chain poly unsaturated fatty acids compared to late sown crop subjected to high temperatures during seed development and oil formation which might have broken the chains/bonds or altered the biochemical processes. Deng and Scarth (1998) reported increase in saturated and monounsaturated fatty acids in seeds produced under high temperature conditions and higher linolenic levels with lower daily temperature during seed development. Sowing on 25 October produced seeds with highest palmitic acid content. Ghosh and Chatterjee (1988) also observed differences in fatty acid composition of oil due to sowing dates.

Cultivar RL 1359 took higher number of days for flowering initiation, 100% flowering and GDD and HTU compared to other varieties (Table 1). However its GDD requirement from flowering initiation to 100% flowering and from 100% flowering to maturity was lowest. Number of siliquae/plant in Kranti and RL 1359 was significantly higher than Varuna (Table 2). Cultivars NRCDR 2 and RL 1359 produced significantly higher number of seeds/siliqua and oil content compared to Kranti and Varuna. The lowest number of branches and siliquae/plant and seeds/siliqua, seed and stalk yields but boldest seeds were recorded in Varuna. THU RL 1359, Kranti and NRCDR 2 being at par with each other outyielded Varuna by margin of 17.1, 13.6 and 13.4%, respectively (Table 2). Similar trend was observed for stalk yield. Interaction of sowing dates with genotypes was non-significant.

Marked differences were observed among cultivars for fatty acid profile except palmitic acid (Table 3). Cultivar NRCDR 2 was superior as it contained higher percentages of oleic, linoleic and linolenic with lower percentage of erucic, palmitic and stearic acids. Ghosh and Chatterjee (1988) and Gaur *et al.* (1993) also observed differences in fatty acid composition in oil of Indian mustard cultivars.

Table 1 **Days taken for different growth stages, growing degree days (GDD) and helio-thermal units (HTU) in Indian mustard (*Brassica juncea* L.) as influenced by sowing dates and cultivars**

Treatment	Flowering initiation			100% Flowering			Maturity			Flowering initiation to 100% flowering		100% flowering to maturity	
	Days	GDD	HTU	Days	GDD	HTU	Days	GDD	HTU	GDD	HTU	GDD	HTU
Sowing dates													
25 September	41	807	7042	51	961	8325	145	1835	14313	154	1283	874	5988
10 October	43	705	5717	52	809	6463	145	1708	12699	104	804	899	6206
25 October	58	690	5296	72	791	5689	143	1611	11570	101	393	820	5881
10 November	66	599	4292	77	693	4847	141	1569	11872	94	556	876	7025
CD (P=0.05)	1.4	16.9	151	2.2	19.0	150	1.2	19.8	165	18.5	159	35	293
Varieties													
Kranti	50	674	5413	62	801	6226	143	1677	12576	127	812	876	6350
Varuna	53	711	5666	63	818	6368	1445	1699	12787	107	701	881	6420
RL 1359	56	742	5813	67	841	6544	144	1692	12711	99	731	851	6167
NRCDR 2	49	674	5454	61	794	6187	142	1654	12350	120	790	860	6163
CD (P=0.05)	1.3	14.5	120	1.7	16.5	129	1.0	15.0	141	13.5	NS	22	192

Table 2 Effect of sowing dates and genotypes of Indian mustard (*Brassica juncea* L.) on yield attributes, yields and oil content

Treatment	Plant height (cm)	Branches/plant		No. of siliquae/ plant	No. of seeds/ siliqua	1000-seed weight (g)	Seed yield (kg/kg)	Stalk yield (kg/ha)	Oil content (%)
		Primary	Secondary						
Sowing dates									
25 September	199	5	11	302	13	6.04	2521	10146	38.0
10 October	203	5	10	277	12	4.81	2672	11412	36.7
25 October	183	4	9	265	12	3.75	1687	7315	35.3
10 November	162	4	8	202	11	3.48	1286	6146	35.1
CD (P=0.05)	12.3	0.5	1.7	58	0.9	0.49	348	1050	1.3
Varieties									
Kranti	188	5	10	289	12	3.96	2089	8990	35.9
Varuna	175	4	9	233	10	5.37	1839	8086	35.7
RL 1359	197	5	10	275	11	4.06	2154	9321	36.2
NRCDR 2	186	5	9	248	13	4.69	2086	8623	37.2
CD (P=0.05)	6.9	0.5	NS	36	0.7	0.21	139	660	1.1

Table 3 Fatty acid composition as influenced by dates of sowing and cultivars of Indian mustard (*Brassica juncea* L.)

Treatment	Fatty acid composition of oil (%)						
	Palmitic (16:0)	Stearic (18:0)	Oleic (18:1)	Linoleic (18:2)	Linolenic (18:3)	Eicosenoic (20:0)	Erucic (22:1)
Sowing dates							
25 September	3.32	1.95	10.6	14.1	13.3	6.47	50.1
10 October	3.2	1.93	11.1	15.7	10.8	6.48	49.6
25 October	3.52	1.95	10.4	15.6	10.8	6.18	51.5
10 November	3.16	1.85	11.0	15.7	10.6	6.53	50.7
CD (P=0.05)	0.20	NS	NS	0.83	0.83	NS	NS
Varieties							
Kranti	3.31	1.94	10.4	15.3	12.5	6.47	50.1
Varuna	3.35	2.07	10.5	14.4	11.0	6.48	52.2
RL 1359	3.44	1.86	11.0	15.6	10.8	6.18	50.8
NRCDR 2	3.21	1.81	11.3	15.7	11.4	6.53	50.0
CD (P=0.05)	NS	0.12	0.67	0.63	1.16	0.29	1.39

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Short communication

Temporal and spatial changes in rapeseed-mustard production in Punjab

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Indian mustard, *Brassica juncea* commonly grown in India occupies 13% of the country's gross cropped area and forms an integral part of the cropping system. Productivity of mustard is greatly influenced by temperature and radiation. In Punjab, rapeseed and mustard currently occupies an area of 51 thousand ha with a production of 61 thousand tonnes and an average yield of 1191 kg/ha.

The present study was planned to assess the changes in spread, production and productivity of rapeseed and mustard in Punjab during the recent three past decades (1970-71 to 1999-2000). Similar studies with wheat (Prabhjyot Kaur *et al.*, 2006) and rice (Singh *et al.*, 2006) crop have been reported for Punjab and for rapeseed-mustard in Haryana (Singh *et al.*, 2004).

The data on area, production and productivity of rapeseed and mustard crops in different districts of the state were collected for the seasons (1970-71 to 1999-2000) from the Statistical Abstract of Punjab. District-wise temporal changes in area, production and productivity were worked out. Furthermore, the period of 30 years was split in 3 blocks of 10 years each which comprised the decades between 1970-71 to 1979-80, 1080-81 to 1989-90 and 1990-91 to 1999-2000 and the spatio-temporal changes were also quantified for the three decades.

Out of 10 districts growing rapeseed-mustard in Punjab occupied first position in terms of area (24.2 thousand ha), third position in terms of production (18.0 thousand tonnes) with an average productivity of 825.6 kg/ha. Amritsar district revealed the highest production (20.3 thousand tonnes) and was second in terms of area (22.5 thousand ha) with a productivity of 907.4 kg/ha. Ferozepur district occupied first position in terms of productivity (996 kg/ha), third in terms of area (19.9 thousand ha) and second in terms of production (18.1 thousand tonnes). Sangrur, Patiala and Jalandhar were other important districts in the state where the crop has shown significant spread and production. The remaining districts of the state were not so important as the area and production was less and productivity was also low.

Area, production and productivity of rapeseed and mustard in 10 districts during the three decades were analysed. A significant decrease in area was noticed in districts of Bathinda, Sangrur and Amritsar while the districts of Jalandhar, Ropar and Ludhiana noticed small increment. However, a significant increase in production was noticed in districts *viz.*, Ludhiana, Ferozepur, Ropar, Jalandhar, Hoshiarpur and Gurdaspur and decrease in Amritsar, Bathinda and Sangrur. However, significant increase in productivity was noticed in other districts.

During the first decade (1970-71 to 1979-80) the Bathinda district occupied maximum area (34.6 thousand ha) and production (22.1 thousand tonnes) while Ferozepur district had highest productivity of rapeseed and mustard crop among the districts. However, during the second decade (1980-81 to 1989-90) the position changed tremendously and Amritsar district became leader in area, production as well as in productivity (1038.2 kg/ha). During the third decade (1990-91 to 1999-2000) the position changed again and the Ferozepur district became the leader in area (19.9 thousand ha), production (23.8 thousand tonnes) as well as productivity (1195.2 kg/ha). Further during the third decade compared to first decade (Table 1), the area under rapeseed and mustard crops in Ropar district increased by 0.75 times followed by 0.43 times in Ludhiana and 0.15 times in Jalandhar. In Sangrur, Bathinda, Amritsar, Patiala and Hoshiarpur districts, the area decreased during the same period. Similarly, the production increased by 1.33 times in Ludhiana, 1.51 times in Ropar, 1.0 times in Jalandhar and 0.77 times in Ferozepur districts. In Amritsar, Sangrur and Bathinda districts, the production decreased by 0.38 to 0.45 times. The productivity level achieved in third decade was higher than that of first decade in all districts and ranged between 0.38 to 1.01 times. The productivity improvement in Patiala and Jalandhar districts was found to be of higher magnitude.

The area under these crops in second decade (1980-81 to 1989-90) increased by 5% or more over first decade (1970-71 to 1979-80) in Jalandhar, Ludhiana, Patiala, Ferozepur and Amritsar districts whereas, Hoshiarpur, Sangrur, Gurdaspur and Bathinda districts experienced a decrease in area of 24% or more (Table 1). Likewise, the production also showed a spectacular increase of more than 60% in Jalandhar, Amritsar and Patiala districts. In other districts where rapeseed and mustard crops occupied significant area, the increase was around 26% or more in Ropar, Ferozepur and Ludhiana. However, in Bathinda and Hoshiarpur districts, the production

decreased by 11 to 18%. The improvement in productivity was significant in Amritsar, Jalandhar, Hoshiarpur, Ropar and Sangrur districts (47, 37, 34, 34 and 30%, respectively), whereas, an improvement in the range of 13 to 28% in productivity was noticed in Patiala, Ferozepur, Ludhiana and Gurdaspur districts.

Accompanying the gain in area and production, there was a significant improvement in the average productivity in all important districts. In third decade compared to first decade, the quantum of increase in area ranged between 15 to 72% in Jalandhar, Ludhiana and Ropar districts while decrease in area ranged between 13 to 69% in Hoshiarpur, Patiala, Amritsar, Bathinda and Sangrur districts. On the production front, Ludhiana district led the scene with an increase of 134.7%. The improvement in productivity was of significant magnitude in Patiala, Jalandhar, Ferozepur and Hoshiarpur districts (101, 81, 71 and 66%, respectively), while an improvement of 38 to 64% in productivity was noticed in Amritsar, Gurdaspur, Ropar, Bathinda, Sangrur and Ludhiana.

A comparison of third decade with the second decade revealed that the quantum of increase in area ranged between 40 to 68% in Gurdaspur and Ropar districts (Table 2). On the contrary, area declined in Jalandhar, Patiala, Bathinda, Ferozepur and Amritsar districts by 25 to 57%. On the production front, Ropar district led the scene with an increase of 74.3%. The improvement in productivity was of significant magnitude in Patiala, Ferozepur, Bathinda and Jalandhar districts (70, 44, 36 and 32%, respectively), whereas, an improvement of 12 to 28% in productivity was noticed in Gurdaspur, Ropar, Sangrur, Hoshiarpur and Ludhiana districts. On the contrary, productivity in Amritsar declined by 5.9% during this period.

Bathinda district revealed the highest area under these crops for the three decades on an average. Amritsar district revealed highest production (20.3 thousand tonnes) but was second in area (22.5 thousand ha) and productivity of these crops (907.4 kg/ha). The average productivity of the crop during the 30-year period was highest in Ferozepur district (9.9.6 kg/ha). Bathinda, Amritsar, Ferozepur, Sangrur and Patiala districts contributed significant share in area and production of rapeseed and mustard crop in the state. The production in Ludhiana district took a jump (more than 134.7% or more increase) during the third decade as compared to the first decade. Similarly, the productivity increased by more than 100% during the third decade over first decade in Patiala district. In general, the rapeseed and mustard during the first decade has been traditionally cultivated over a large area in the south-western districts of Punjab state. However, the productivity of these crops increased during third decade over the first decade by more than 60% in central irrigated zone of Punjab *viz.*, Patiala (101%), Jalandhar (81%) and Ludhiana (64%). This indicates that potential productivity of rapeseed and mustard crops can be achieved by growing these in Ferozepur, Jalandhar, Ludhiana, Sangrur, Bathinda and Patiala districts of the state. Such information is useful for the policy planners while preparing crop diversification programmes for the state.

Table 1 Decadal-wise shift (%) in area, production and productivity of rapeseed and mustard in Punjab

District	Area				Production				Productivity			
	A	B	C	Mean	A	B	C	Mean	A	B	C	Mean
Gurdaspur	-26.1	3.6	40.2	5.9	2.7	49.6	45.7	32.6	27.4	43.0	12.2	27.5
Amritsar	5.0	-54.7	-56.8	-35.5	61.3	-38.0	-61.5	-12.7	46.8	38.0	-5.9	26.3
Jalandhar	53.4	14.8	-25.2	14.3	106.5	100.0	-3.1	67.8	37.4	81.1	31.8	50.1
Hoshiarpur	-30.1	-12.7	24.9	-6.0	-17.5	41.9	72.0	32.1	34.3	65.7	23.4	41.2
Ropar	3.0	72.4	67.5	47.6	26.7	121.4	74.8	74.3	34.2	51.8	13.1	33.0
Ludhiana	19.5	41.0	17.9	26.1	57.1	134.7	49.4	80.4	28.2	64.4	28.3	40.3
Ferozepur	7.4	3.3	-3.8	2.3	27.8	77.2	38.6	47.9	18.8	70.5	43.5	44.3
Bathinda	-24.4	-65.8	-54.8	-48.3	-11.2	-44.5	-37.5	-31.1	13.4	53.6	35.5	34.1
Sangrur	-28.2	-69.0	-56.8	-51.3	0.2	-45.3	-45.4	-30.2	29.8	55.9	20.2	35.3
Patiala	8.3	-28.8	-34.2	-18.2	60.5	57.8	-1.7	38.9	18.3	101.2	70.2	63.2

A = Represent shift during second decade over first decade; B = shift during third decade over first decade; C = shift during third decade over second decade

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Short communication

Studies on growth, yield, land equivalent ratio and economics of toria, *Brassica rapa* var *toria* and berseem, *Trifolium alexandrinum* intercropping system

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India is the largest nation in cattle population. The supply of edible oils to man and fodders to cattle is not sufficient. The land utilized for growing green fodder crops hardly exceed 5% of the cultivated area with no scope to further increase. The energy rich oilseed and leguminous fodder crops are often grown in energy starved regions. Barik *et al.* (1997) suggested that their productivity has to be increased in net sown area by growing the fodder crops along with the oilseed crops. Rapeseed is an emergency pasture crop and fits well in intercropping systems to provide potential roughage during the lean periods with the added advantage that it performs well in saline and alkaline soils even with poor quality irrigation water. Downey and Rimmer (1993) prophesized that the brassica crops are destined to play an ever increasing role in the supply of worlds' food, feed and industrial needs in the next century. Hence, this experiment was conducted to investigate the optimum row ratio of toria and berseem for intercropping on physically poor soil with crust formation and saline irrigation water.

The experiment was conducted during *rabi* 2003-04 at the Agricultural College Farm, Rajendranagar, Hyderabad on a sandy loam soil. It was moderately alkaline with pH 7.9, non-saline with ECe of 0.156 dS/m and having low organic carbon content of 0.45%. The available nitrogen was very low (170 kg/ha N), phosphorus was medium (24.6 kg/ha P) and rich in potassium (240 kg/ha K). The experiment was laid out in a Randomized Block Design with eight treatments in three replications. One and two rows of toria were intercropped in a replacement series with 1, 2 or 3 rows of berseem apart from their sole crops in plots of 7.2 x 4.5 m. The spacing was 30 cm between the rows. Toria was fertilized with 40:30:30 kg/ha NPK. Berseem was fertilized with 30:50:30 kg/ha NPK and supplemented with 25 kg/ha N after 1st and 2nd cut. In intercropping treatments fertilizers were applied as per the proportional density of the crops. Berseem was harvested for green fodder at 67 and 99 days and at 175 days for seed and crop residues. Toria was harvested at 94 days. A total of 15 irrigations were applied to berseem in sole and intercropping systems while 7 irrigations were given to toria with saline water having ECw 3.37 dS/m and pH 7.3. Land equivalent ratio was calculated separately for seed and fodder yield due to their biological differences as suggested by Willey and Osiru (1972). The relative net returns index was worked out following the approach suggested by Jain and Rao (1980). The results showed that the plant height of toria intercropped with berseem in 1:1, 2:1 or 2:2 row proportions was on par with the sole crop (Table 1). But, the inter specific competition significantly reduced the plant height due to increase in row proportion of berseem in other treatments. Toria produced significantly more number of primary branches/plant in all the intercropping systems probably due to the shading effect. But, the number of secondary branches, phytomass accumulation, number of siliquae/plant and number seeds/siliqua were not significantly different from the sole crop. The seed yield was significantly low and reduced more with increasing proportion of intercropped berseem. The sole crop yielded 4.7 q/ha seed yield. In intercropping system with 2:1 and 2:1 row proportion, it yielded 3.10 and 3.0 q/ha. The stover yield was 27.0 q/ha from these treatments which was on par with 34.0 q/ha in the sole crop. The plant height and number of branches/plant of berseem were not significantly influenced by the intercropping treatments at the first or second cut (Table 2). Barik *et al.* (1997) also reported similar results in berseem and lucerne intercropped with oats. Green fodder yield of 11.9 q/ha was obtained in the 1st cut and 29.0 q/ha in the 2nd cut from sole berseem. The fodder yield reduced significantly in all the intercropping treatments. The best intercropping row proportion of toria-berseem was 1:3 or 2:3. Green fodder yield of 6.0 and 5.0 q/ha was harvested in the 1st cut while, 14.1 and 14.2 q/ha in the 2nd cut from the corresponding treatments. The trends were similar for seed yield. The sole crop produced 0.69 seed and 4.0 q/ha residue. The intercropped berseem in 1:1 row proportion yielded 0.5 q seed and 2.6 q/ha residue. In the 2:3 row proportion the seed yield was 0.23 q/ha and the residue yield was 2.4 q/ha.

The land equivalent ratio of 1.12 established that the intercropping of toria-berseem in 1:3 row proportion was

the best to realize 12% more seed yield/unit area of land (Table 3). The best intercropping advantage for the production of fodders was realized in 2:2 row proportion with maximum land equivalent ratio of 1.16. Maximum net returns/rupee investment were obtained from the sole crop of toria. But, the relative net returns index which is the sound statistical approach for precise economic evaluation showed that the profits from any intercropping system were not significantly different. Therefore, intercropping of toria-berseem in 2:2 row proportion seem to be the best strategy to obtain rational feed constituting the protein rich fodder from berseem along with the roughage including stover from toria for the cattle on one hand and still realize about 65% sole optimum seed yield of toria and 27% sole optimum seed yield of berseem.

Table 1 Growth, yield components, oil content and yield of toria as influenced by the proportion of intercropping with berseem

Intercropping toria : berseem	Plant height (cm)	No. of branches/plant		Phytomass (g/plant)	No. of siliquae/plant	No. of seeds/ siliqua	Oil content (%)	Yield (q/ha)	
		Primary	Secondary					Seed	Stover
1:1	101	8	7	9.2	372	9	29.0	2.90	21
1:2	97	8	8	9.0	366	9	28.2	2.20	18
1:3	98	7	7	9.1	323	10	29.1	1.80	11
2:1	100	8	8	9.3	352	9	29.0	3.10	27
2:2	99	7	8	8.3	332	9	28.8	3.00	27
2:3	93	7	6	7.5	232	9	29.1	2.20	17
Sole	109	6	7	8.1	362	10	30.1	4.7	34
SEm±	3	0.3	0.7	0.7	51	0.3	0.4	0.4	3
CD (P=0.05)	10	0.9	NS	Ns	NS	NS	1.2	1.10	10

Table 2 Growth and yield of berseem as influenced by the proportion of intercropping with toria

Intercropping Toria : berseem	Plant height (cm)		No. of branches/ plant		Yield (q/ha)			
					Green fodder		Seed	Residue
	67 DAS	*99 DAS*	*1st Cut*	*2nd Cut*	*1st Cut*	*2nd Cut*		
1:1	28	29	3	5	4.4	7.5	0.19	1.1
1:2	24	32	3	6	5.3	10.3	0.26	2.1
1:3	24	29	4	6	6.0	14.1	0.50	2.6
2:1	29	35	3	6	3.2	5.1	0.11	0.9
2:2	24	31	3	5	4.8	8.8	0.19	1.5
2:3	25	29	3	6	5.0	14.2	0.23	2.4
Sole	26	30	4	6	11.9	29.0	0.69	4.0
SEm±	2	2	0.4	0.5	0.4	1.4	0.02	0.2
CD (P=0.05)	NS	NS	NS	NS	1.2	4.3	0.06	0.5

Table 3 Land equivalent ratio and economics of toria : berseen intercropping systems

Intercropping toria : berseem	Land equivalent ratio		Net returns (Rs/Re)	Relative net returns index (RNR)
	Seed	*Stover + Fodder*		
1:1	0.89	0.92	0.11	0.94
1:2	0.85	0.99	0.08	0.93
1:3	1.12	0.89	0.27	1.13
2:1	0.82	1.02	0.08	0.91
2:2	0.92	1.16	0.13	0.97
2:3	0.80	1.02	0.31	1.09
Sole toria	1.00	1.00	0.48	-
Sole berseem	1.00	1.00	0.15	-
SEm±	-	-	-	0.11
CD (P=0.05)	-	-	-	NS

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Short communication

Fertilizer management in intercropping systems involving castor or sunflower under rainfed conditions

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The major area under oilseed crops, particularly castor and sunflower, is under rainfed conditions. Intercropping system provides insurance against risks to the rainfed farmers under aberrant weather conditions besides better use of natural resources, *viz.*, sunlight, land and water. Castor and sunflower, owing to their cultivation under wider spacing, provide better opportunity to raise intercrops. Based on the studies carried out under the All India Coordinated Research Project on Oilseeds, promising intercropping systems involving castor or sunflower have been recommended. The successful cultivation of sunflower + pigeonpea intercropping system in Maharashtra is advocated by Bhalerao *et al.* (1993) under rainfed conditions. Guggari *et al.* (2003) reported that castor + pigeonpea intercropping system is more sustainable compared to sole cropping of castor in Karnataka. The nutrient requirement of sunflower + pigeonpea intercropping system has been reported by Shanwad *et al.* (2001) in vertisols of Karnataka. However, in Alfisols of Telangana region of Andhra Pradesh, there is need to workout the nutrient requirement of intercropping system involving castor or sunflower. To derive the highest yield advantage from intercropping system, the nutrient requirement of intercropping system differs with that of individual sole cropping. When two crops of dissimilar nutrient requirements are grown together, it sometime becomes practically difficult to meet the nutrient deeds of component crops simultaneously. Therefore the present investigation was undertaken to assess the fertilizer needs of the promising intercropping systems involving castor or sunflower under rainfed conditions in Alfisols.

Field experiments were conducted at the research farm of Directorate of Oilseeds Research, Hyderabad on a red sandy soils for three years (1999-2000, 2002-03 and 2003-04) with an objective to identify nutrient use efficient and highly productive intercropping systems involving either castor or sunflower as component crop. The experiment was not successful during 2000-01 and 2001-02 due to frequent drought. The soils were low in N (organic carbon 0.45%) and P (7.6 kg P_2O_5/ha) and medium in K (219 K_2O kg/ha) having pH 6.8. The treatments comprised of six intercropping systems in combination with two fertilizer management practices. The intercropping systems were castor+pigeonpea (1:1), castor+sunflower (1:2), castor + clusterbean (1:2), castor + groundnut (1:5), sunflower + groundnut (1:5) and sunflower + pigeonpea (2:1) each with two fertilizer management levels *viz.*, I) recommended fertilizer dose of castor/sunflower to the system and ii) recommended fertilizer dose of both crops on area basis to the system. Thus, there were twelve treatments tested in three replications in randomized block design. Sole crop of castor, sunflower and intercrops were raised in adjacent plots for the purpose of computing LER. The recommended dose of fertilizer ($N:P_2O_5:K_2O$ kg/ha) applied to different crops was 40:40:0 for castor; 60:40:30 for sunflower, 20:50:0 for pigeonpea, 20:40:20 for groundnut and 20:50:0 for clusterbean as per the treatments. Castor (cv DCS 9), sunflower (cv. Morden), pigeonpea (cv. ICPL 127), clusterbean (cv. Pusanavbahar) and groundnut (cv. ICGS 11) were sown with the onset of monsoon. Nitrogen was applied in two equal splits, at sowing and 30 days after sowing in sunflower and 45 days after sowing in castor. Phophorus and potassium were applied as basal dose. The total rainfall received during crop season (June to December) was 449 mm in 1999-2000; 392 mm in 2002-03 and 776 mm in 2003-04 (Fig.1).

Pooled analysis for castor/ sunflower equivalent seed yield was done and years were found to be significantly different and therefore year wise data were presented. The three years of experimentation were differed in respect of total amount and distribution of rainfall during crop season. The amount of rainfall received during crop season was 449, 392 and 776 mm in *I*, *II* and *III* years of experimentation, respectively. Seed yield of sole crop as well as intercrop of sunflower did not differ between the years of experimentation. However, seed yields of sole and intercrop of castor differed between the years of experimentation. It could be due to the short duration of sunflower and long duration castor.

Equivalent yields: Equivalent yield of castor/sunflower differed significantly due to intercropping system, while the performance of the intercropping systems was not significantly influenced by the fertilizer practice (Table 1). In the first year of experimentation, intercropping of castor

with groundnut (1:5) recorded significantly highest castor equivalent yield (1004; 1227 kg/ha). It could be due to the well distributed rainfall (though average is less than normal) which favored higher yield of groundnut. However, in the second year of experimentation, where rainfall is nearly half of normal rainfall, equivalent yield of castor was significantly higher with castor + clusterbean (1889 kg/ha) followed by castor + pigeonpea (1328 kg/ha) intercropping. Padmavathi and Raghavaiah (2004) also reported that castor + clusterbean intercropping is better option for maximizing the productivity and profitability in subnormal rainfall years and to minimize risk in drought years. In the third year, a normal rainfall year, castor equivalent yield was significantly highest with castor + pigeonpea (1:1) intercropping system. Castor + pigeonpea intercropping system performed better both in stress year and well distributed rainfall year. Castor yield decreased with sunflower due to competition for resources which resulted in ultimate lower castor equivalent seed yield. Similar results were also reported by Guggari *et al.* (2003). There was no significant differences in the fertilizer treatments. It is better to apply fertilizer based on the area basis of component crops. On red sandy loam soils of Bangalore, higher yields and net returns were realized from the sunflower + pigeonpea intercropping when both were supplied with their respective recommended fertilizer (Sudhakara Babu, 1993). During first and second year of experimentation, the sunflower equivalent yield was significantly higher in sunflower + groundnut which was on par with sunflower + pigeonpea intercropping system. It indicates that under low (400-450 mm) rainfall situations, intercropping of sunflower either with groundnut or pigeonpea was better choice. In normal rainfall year (third year) intercropping of sunflower with pigeonpea was significantly superior to sunflower + groundnut intercropping system. Well distributed rainfall upto end of October might have influenced the pigeonpea favourably and 3-4 week dry spell during September probably have affected the groundnut, which reflected in seed yield.

LER: Among the intercropping systems involving castor, castor + clusterbean recorded maximum LER of 1.30 at recommended dose of fertilizer level of both crops on area basis, whereas the intercropping systems involving sunflower + pigeonpea intercropping system recorded highest LER of 1.36.

Economics: Among the intercropping systems involving castor/sunflower, intercropping of castor or sunflower with pigeonpea recorded highest B:C ratio. This is because of higher productivity of pigeonpea and remunerative price.

It can be inferred that intercropping system with pigeonpea either castor or sunflower is more productive and profitable. It is desirable to apply recommended dose of fertilizer of main crop to the system or recommended fertilizer dose of both crops on area basis depending o the economy of application of nutrients.

Table 1 Year-wise seed yield (kg/ha) of sole and intercrops and equivalent seed yield of castor/sunflower

Intercropping system	Fertilizer level	Castor / Sunflower Seed yield (kg/ha)				Intercrop yield (kg/ha)				Castor / Sunflower equivalent yield (kg/ha)				Mean LER	B:C ratio
		I year	II year	III year	Av.	I year	II year	III year	Av.	I year	II year	III year	Av.		
Castor + Pigeonpea (1:1)	F_1	356	558	692	535	165	1447	1026	879	527	1447	2011	1328	1.07	2.51
	F_2	277	605	530	471	175	1435	1023	878	438	1435	1875	1249	1.00	2.41
Castor + Sunflower (1:2)	F_1	381	167	298	282	652	1278	1030	987	852	1278	1617	1249	1.07	2.26
	F_2	232	318	289	246	1022	1299	898	1073	972	1299	1443	1238	1.14	2.32
Castor + Clusterbean (1:2)	F_1	413	381	577	457	3275	3155	6930	4453	865	3155	1567	1862	1.18	1.87
	F_2	630	407	730	589	3061	2748	7276	4362	1052	2748	1867	1889	1.30	2.07
Castor + Groundnut (1:5)	F_1	542	410	402	451	559	929	961	816	1004	929	1432	1122	1.05	2.03
	F_2	319	490	670	493	1097	826	821	915	1227	826	1549	1201	1.09	2.27
Sunflower + Groundnut (1:5)	F_1	378	496	314	396	1182	880	862	975	1729	880	1032	1214	0.98	2.13
	F_2	394	680	409	494	789	680	977	815	1296	680	1223	1066	0.95	1.96
Sunflower + Pigeonpea (2:1)	F_1	838	1274	1038	1050	449	1274	1123	949	1480	834	2161	1492	1.36	3.10
	F_2	902	1313	816	1010	262	1313	1126	900	1374	877	1942	1398	1.30	3.01
Intercropping system															
S Em±															
C D (P=0.05)										145	159	119			
Fertilizer level										428	331	348			
S Em±										81	93	69			
C D (P=0.05)										NS	NS	NS			
Sole crops															
Castor		780	975	1038	931										1.87
Sunflower		1248	1343	1245	1279										2.43
Pigeonpea		579	2261	450	1763										
Clusterbean		6061	4044	9351	6485										
Groundnut		1971	1100	1256	1442										

F_1 : Recommended dose of fertilizer of main crop to the system

F_2 : Recommended dose of fertilizer of main crop and intercrop based on area basis

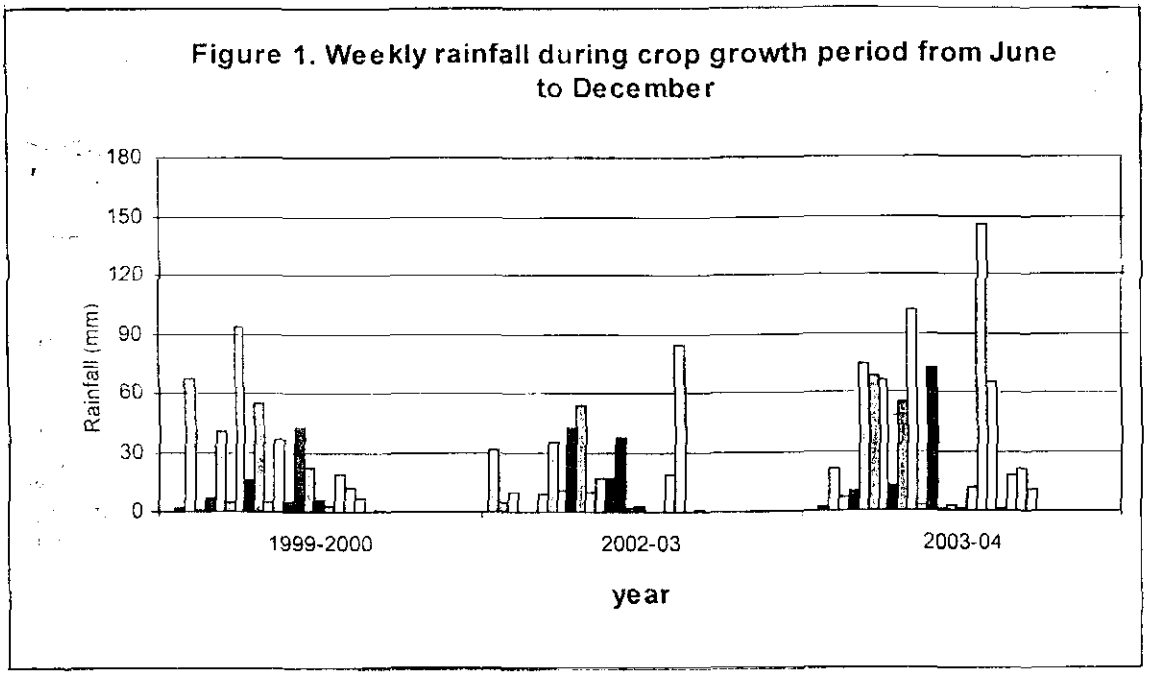

Fig. 1. Weekly rainfall during crop growth period from June to December

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Short communication

Study on castor, *Ricinus communis* L. based Intercropping system under rainfed conditions

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Castor is the second most important oilseed crop of Andhra Pradesh in terms of acreage and economy after groundnut. For the last 10 years, castor is being cultivated in 2.5 - 4.0 lakh ha in Andhra Pradesh. It is the lifeline for the farmers of Mahaboobnagar district and 60-70% of Andhra Pradesh castor production comes from this district only. In addition to this, Ranga Reddy, Nalgonda, Prakasam, Medak and Warangal are the other castor growing districts. All the castor growing areas of Andhra Pradesh are characterized by low and erratic rainfall, shallow sandy soils and resource poor farmers. It is very essential to intensify the efforts on cropping system in order to sustain the income of castor growing farmers. Among the various management options, intercropping is one of the important management strategy to mitigate the aberrant climatic conditions. In normal rainfall year sunflower + pigeonpea intercropping system could be more economical in terms of seed equivalent of sunflower, gross and net monitory returns (Gouri *et al.*,1997). However intercropping of short duration leguminous crops like greengram, blackgram and clusterbean with castor is remunerative (Singh and Singh, 1988) for dryland conditions. Among the different intercropping systems, the maximum monetary advantage of Rs.3,907/ha was recorded in castor + greengram followed by castor + blackgram (Gupta and Rathore, 1993). In view of the above situation, the present investigation was undertaken to select the best rainy season crops for intercropping with castor for increasing net returns.

The field experiment was conducted during the rainy season of 2002-03 on sandy-loam soil under rainfed conditions at RARS, Palem. The soil of the experimental site was sandy loam with neutral pH ; low in available nitrogen (165 kg/ha); medium in available phosphorus (38.5 kg/ha) and high in available potassium (395 kg/ha).The experiment was laid out in Randomised Block Design and replicated four times. The treatments consisted of sole castor (in paired row planting), castor + pigeonpea 1:1 (normal planting) castor + greengram, castor + sunflower, castor + maize and castor + pigeonpea intercropped in between two pairs of castor (60/120x60cm). Castor variety "Haritha", greengram ML-267, maize DHM-103, sunflower (Morden) and pigeonpea (PRG-100) were used. Castor was sown on 22nd July 2002 in paired row planting (60/120x60cm) and two rows of greengram, pigeonpea, sunflower, one row of maize and pigeonpea were taken in between pairs. All the recommended crop management practices were followed as and when required. Castor was fertilized with 60-40-30 kg NPK/ha. Total quantity of P and K was applied as basal and N was applied in three splits *viz.*, 1/3rd as basal, 1/3rd at 30-35 DAS and 1/3rd at 60-65 DAS. The crop received a rainfall of 436 mm during the growth period as against the normal of 646 mm. Seed yields of component crops were converted into castor equivalent seed yields, considering the prevailing prices of produce during the year.

The results showed that seed yields were not influenced significantly by intercropping system, however the highest castor seed yield was (1265 kg/ha) was recorded in castor + pigeonpea (2:1) followed by castor + greengram (1157 kg/ha), castor + pigeonpea (1150 kg/ha) (normal planting) and sole castor (1130 kg/ha). But the castor yields were reduced when it was intercropped with sunflower (860 kg/ha) and maize (1003 kg/ha) when compared with sole castor (1130 kg/ha). The maximum reduction (23.89%) in castor yield was recorded when it was intercropped with sunflower followed by maize (11.23%). Gupta and Rathore (1993) observed maximum reduction (46.26%) in castor yield when it was intercropped with maize. The minimum reduction in castor seed yield was recorded when it was intercropped with blackgram (9.21%) followed by groundnut (9.6%), soybean (21%) and greengram (22%).

Castor + pigeonpea (normal planting), castor + pigeonpea (paired row planting) intercropping significantly influenced the castor equivalent seed yield when compared to sunflower and maize intercropping (Table 1). There was better seed yield of pigeonpea in both plantings because of their temporal and spatial complementarity. Greengram crop failed because of moisture stress during growth period, where as sunflower and maize also recorded low yields when intercropped with castor because of coincidence of flowering with dry spell.

Economic evaluation in terms of gross and net returns showed that pigeonpea intercropped in paired row planting and normal row planting recorded highest net returns of Rs.18137 and Rs.12262/ha, respectively. These two systems also showed an additional advantage of highest net returns of Rs.7654/ha and Rs.1779/ha in 2:1 and 1:1 intercropping system, respectively. Based on gross returns, net returns, additional net returns and castor equivalent yield, intercropping of pigeonpea 2:1 was found highly remunerative intercropping system.

Table 1 Economics of intercropping system in rainfed castor on Alfisols

Treatment	Yield of castor (kg/ha)	Yield of intercrop (kg/ha)	Castor equivalent yields (kg/ha)	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	Additional returns (Rs./ha)
T_1 Castor sole crop	1130	--	1130	9857	20340	104823	–
T_2 Castor + Pigeonpea (1:1)	1150	134	1276	10715	22978	12262	1779
T_3 Castor + Greengram (2:2)	1157	--	1157	9857	20826	10969	486
T_4 Castor + Sunflower (2:2)	860	336	1068	11252	19176	7924	-2559
T_5 Castor + Maize (2:1)	1003	194	1056	10982	19024	8042	-2441
T_6 Castor + Pigeonpea (2:1)	1265	344	1590	10481	28618	18137	7654
SEm ±	230		36				
CD (P= 0.05)	NS		110				

Price of castor: Rs.18/kg; Pigeonpea : Rs.17/kg; Sunflower : Rs.11/kg; Maize : Rs.5/kg

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Short communication

Response of linseed, *Linum usitatissimum* L. varieties to row spacing and phosphorus level under irrigated condition

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Linseed (*Linum usitatissimum* L.) is an important oilseed crop for its industrial value. It is grown both under rainfed and irrigated conditions in India. The oil of linseed is a major raw material for surface coating industry with a sizeable portion being used for edible purpose. But it is chosen for a piece of land where only dryland crop can be grown or placed under different mixed cropping system to cover risk against the natural hazards under such condition there is hardly any crop as remunerative as the linseed. The area under linseed in Marathwada region of Maharashtra state was 16000 ha with an annual production of 5000 tonnes and average productivity was 312 kg/ha (Anonymous, 2006). Very little work on production technology of this crop has been done in Marathwada region. Therefore, an experiment was conducted to find out the suitable variety, row spacing and phosphorus level.

A field experiment was conducted at Agriculture College farm, Latur, Marathwada Agricultural University, during *rabi* season 2006-07. The soil of experimental plot was deep black with good drainage. The soil was clayey in texture (sand - 21.24 %, silt- 24.60 % and clay - 54.16%), slightly alkaline in reaction having pH 8.05, EC 0.29, low in organic carbon (0.22 %), available nitrogen (205 kg/ ha), phosphorus (20.81 kg/ ha) and high in potassium (479 kg/ha). The experiment was laid out in Split Plot Design with three replications. The treatment consists of three-row spacing (22.5, 30, 37.5 cm) and two varieties (RLC-4 and Garima) in main plot and three phosphorus levels (25,50 and 75 P_2O_5 kg/ha) in sub plot.

The sowing of the linseed crop was undertaken on 3rd October, 2006 by dibbling method at the depth of 5 cm. Two thinning operations were carried out, at 10 and at 21 days after sowing. The crop was given light irrigation immediately after sowing to ensure proper germination and uniform plant stand. The crop was irrigated twice, first at 33 days after sowing and second at 68 days after sowing. Recommended dose of fertilizer i.e., 50 kg N and 25 kg K_2O/ha were applied as a basal dose uniformly to all plot at the time of sowing. The phosphorus levels were applied as per treatments at the time of sowing.

The growth characters like plant height, number of branches and total dry matter accumulation was recorded significantly higher by the variety RLC-4 than Garima (Table 1). The yield attributes like mean number of capsules/plant and thousand-grain weight was found significantly higher in RLC-4 than Garima. Among varieties RLC-4 recorded significantly higher grain yield (1439 kg/ha) and straw yield (2412 kg/ha) with harvest index (37.4 %). The variety RLC-4 recorded 22.58% increase in yield over Garima. The significantly higher oil percent (39.2 %) and oil yield (562 kg/ha) was recorded by the variety RLC-4 over Garima.

The increased plant height was observed when linseed crop was sown at 22.5 cm and 30 cm row spacing whereas number of branches per plant and total dry matter accumulation was higher at 37.5 cm row spacing. Number of capsules per plant and thousand-grain weight was significantly higher with 37.5 cm row spacing. Singh and Verma (1993) reported that wider row spacing recorded more branches/plant, capsule/plant, seeds/capsule and 1000-grain weight, which in turn resulted in higher yield compared with narrow spacing.

The higher grain yield (1442 kg/ha), straw yield (2417) and oil yield (546 kg/ha) was observed at 22.5 cm row spacing and remains at par with 30 cm row spacing. Khare *et al.* (1996) reported that sowing of linseed at 30 cm row spacing gave significantly higher yield than 25 cm row spacing.

The growth characters like plant height, number of branches and total dry matter accumulation were higher with the application of 75 kg P_2O_5/ha. Similarly the various yield attributes like mean number of capsules and 1000-grain weight were significantly higher at 75 kg P_2O_5/ha, however it was found at par with 50 kg P_2O_5/ha and significantly superior over 25 kg P_2O_5/ha. Jain *et al.* (1989) reported that application of phosphorus increased the grain yield significantly. Similar trend was also reported by Nema *et al.* (1977). Yield attributes like number of capsule/plant and 1000-seed weight were also significantly influenced by phosphorus application.

Higher grain yield (1412 kg/ha), straw yield (2412) and harvest index (38 %) was recorded with application of 75 kg P_2O_5/ha. Nagaraja *et al.* (1997) revealed that application of 80 kg/ha resulted in 23.07, 7.0, 16.8 and

26.2% increase in seed, straw, fibre and oil yield, respectively. Oil yield (640 kg/ha) was significantly increased at 75 kg P_2O_5/ha as compared to other levels of phosphorus However it was found at par with 50 kg P_2O_5/ha. Chaubey *et al.* (1992) reported that phosphorus and sulphur increased significantly the oil content of linseed and high oil content was recorded at higher dose of P&S (50 kg and 60 kg/ha respectively).

The interaction effect between spacing and phosphorus levels on seed yield and straw yield was found significant. The interaction effect between spacing and phosphorus levels revealed that the 22.5 cm spacing with application of 75kg P_2O_5/ha significantly increased the seed yield (1442 kg/ha) and straw yield (2412 kg/ha) over other treatments.

Table 1 Growth, yield components, grain and straw yield, oil content & oil yield of linseed as influenced by different varieties and phosphorus levels

Treatment	Plant height (cm)	Branches /plant	Plant stand (%)	Dry matter/ plant(g)	No of capsule / plant	1000 seed wt. (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Oil content (%)	Oil yield (Kg/ha)
Varieties											
RLC-4	67	11	87	12	37	7.8	1439	2412	37.4	39.2	562
Garima	61	10	86	9	32	7.4	1114	2050	35.2	37.8	421
CD(P=0.05)	2.2	0.7	NS	0.2	3.6	0.3	201	191	0.9	0.35	35
Spacing (cm)											
22.5	65	10	87	11	33	7.4	1442	2417	37.4	37.9	546
30	65	10	86	11	33	7.4	1392	2362	37.1	38.2	531
37.5	62	11	87	11	39	7.5	1200	2163	35.7	38.3	459
CD(P=0.05)	2.2	0.7	NS	0.2	3.5	NS	192	196	0.9	NS	39
Phosphorus											
Level (kg/ ha)											
25	62	10	87	11	31	7.4	1186	2312	33.9	37.8	448
50	65	12	87	12	37	8.5	1401	2400	37.9	39.1	633
75	65	12	86	12	38	8.7	1412	2412	38	39.3	640
CD(P=0.05)	2.4	1.6	NS	1.1	5.2	NS	143	193	0.93	NS	142

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Short communication

Field evaluation of *Nomuraea rileyi* (Farlow) Samson formulations and spray equipments for the management of Tobacco caterpillar, *Spodoptera litura* (F.) on groundnut

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To manage the noxious pest, *Spodoptera litura* (F.) by eco-friendly approach, *Nomuraea rileyi* (Farlow) Samson an entomopathogenic fungus has been identified as a potential candidate (Ramegowda, 2005). *Nomuraea rileyi* performs well under high humid regions like transitional belt of northern Karnataka and coastal Karnataka and in groundnut and soybean. But, it failed to do so under low relative humidity and higher temperature prevailing regions such as northern dry zone of Karnataka (Lingappa and Patil, 2002; Ramegowda, 2005 and Wightman and Ranga Rao, 1994). Laboratory studies showed that 4% sunflower oil based tank mix formulation of *N. rileyi* is very efficient against *S. litura* and *H. armigera* (Kulkarni, 1989; Nagaraj *et al.*, 2006). With these in the background, it was thought of extending the geographical utility of this fungus by deploying formulations of *N. rileyi* and different spray equipments. A field experiment was undertaken with three formulations of *N. rileyi* and three spray equipments to know their suitability in groundnut against *S. litura* at Main Agricultural Research Station, Dharwad during the *kharif* season of the drought hit year, 2003.

Dharwad is situated in the transitional tract of Karnataka (zone 8) at 15°26' north latitude and 75°07' east longitude with an altitude of 678 m above MSL and has mild tropical rainy climate. The mean annual rainfall of Dharwad is about 751 mm distributed over a period of seven to eight months (April to November) with two distinctive peaks occurring in July and October. Relative humidity and temperature ranges from 40 to 85% and 11° to 37°C, respectively. During the experimental year the rainfall was 977.3 mm, the max. and min. temperature ranged between 24.2 to 31.5°C and 18.3 to 21.7°C and the RH in the morning and evening was 53 to 91 and 26 to 89%, respectively during the cropping seasons as against the normal values mentioned above.

Three formulations of *N. rileyi viz.*, four percent sunflower oil based tank mix formulation (F_1), talc based wettable powder formulation (F_2) and unformulated crude form (F_3) of *N. rileyi* grown on broken rice were sprayed using high volume (Knapsack- Aspee®, 16 l; E_1), low volume (Power-Aspee Bolo®, 10 l; E_2) and ultra low volume (Battery operated -Thompson® -Heli Spray, 1 l; E_3) sprayers against *S. litura* in groundnut.

Above said formulations of *N. rileyi* were prepared as per the protocol followed by Nagaraj *et al.* (2006). The oil formulation (F_1) was prepared by extracting the spores directly by using the sunflower oil and Tween 80® (the end product concentration of oil was 4% and that of Tween 80® was 0.02%). The WP formulation (F_2) was prepared by harvesting the *N. rileyi* spores in sterilized talc powder, blended with Tween 80® 0.02% and dried aseptically. The crude form of *N. rileyi* (F_3) was just aseptically dried culture grown on rice grains, from same batch used for other two formulations. The trial was laid out in Split Plot Design with three replications with a plot size of 5 m 3 m leaving gangway of one meter all around the plot. Groundnut cultivar JL-24 was sown at a spacing of 30x10 cm during fourth week of June. All these formulations were evaluated at $2x10^{11}$ conidia/ha with different equipments *viz.*, high volume, low volume and ultra low volume sprayer delivering a total spray volumes of 1.8, 0.6 and 0.075 l/ plot of 15 m^2, receptively. The total number of larvae and diseased larvae per meter row was recorded at five spots in each replicated treatment at 5, 10, 15 days after spray and assessment of leaflet damage was also made by visual scoring at 5, 10, 15 days after each spray. The fungal formulations were evaluated in comparison to chemical spray of quinalphos (2ml/l) (1st spray) followed by cholrpyriphos (2ml/l) (2nd spray) (RPP) and the spray of water (UTC). The first spray was imposed on 40 days old crop and second one, 15 days later. The data on disease incidence, leaflet damage and yield were subjected to statistical analysis after necessary transformations and the means were separated by DMRT to differentiate superiority of the treatments.

Mycosis: A day before application of treatments the larval population of *S. litura* was uniform and above ETL throughout the experimental arena. The impact of

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formulations of *N. rileyi* and spray equipments measured as the disease incidence on *S. litura* expressed in percent mycosis at 5, 10 and 15 days after each spray (Tables 1 and 2).

Five days after first spray, significantly higher percent disease incidence was recorded in oil formulation (F_1) (41.58%) followed by wettable powder (F_2) (31.88%). High volume spray with Knapsack sprayer (E_1) recorded significantly higher percent mycosis (26.71%) irrespective of spray formulation. Maximum mycosis was noticed in oil based formulation sprayed with Knapsack sprayer (47.08%). The same trend was observed in the observations recorded after 10 and 15 days of first spray as well as the second spray too at all the three intervals of *observations, with respective figures* (Table 1 and 2).

Leaflet damage: The formulations of *N. rileyi* failed to differentiate themselves with respect to leaflet damage inflicted by *S. litura* at five days after the first spray (Table 3), But, at the later intervals, sunflower oil based formulation proved to be superior in offering greater protection from *S. litura* reflected by lower leaflet damage irrespective of the equipments deployed for the spray. *Similarly, the high volume and low volume sprayers were* indifferent from each other and were superior to ULV in offering better protection in terms of leaflet damage. The observations after second spry clearly depicted the superiority of oil-based formulations of *N. rileyi* in reducing the leaflet damage at all the three intervals (Table 4). The superiority of high and low volume sprayers over ULV observed at 5 and 10 days after second spray was not visible at 15 days.

Pod yield: Formulations of *N. rileyi* as well as spray equipments significantly influenced pod yield. The statistical similarity between pod yields of untreated control and unformulated crude form of *N. rileyi* clearly demonstrated the need for formulations. Sunflower oil based tank formulation of *N. rileyi* (F_1) yielded highest pod yield and was significantly superior to the rest two formulations and was on par with chemical application. Among the equipments, high volume sprayer (E_1) emerged as the best sprayer for formulations of *N. rileyi* and it has yielded 10.42 q/ha when used with oil formulation. Higher efficacy of oil based formulation in groundnut crop ecosystem on *S. litura* might be due to the fact that oil wets the dry and dusty conidia, allowing it to suspend easily in water and spread rapidly over the surface of leaves. This helps in enhancing contact of conidia with insect cuticle and enabling conidia to reach the protected spaces between the enfolded intersegmental membranes which helps easy penetration of the fungus into insect body for further multiplication (Burges, 1988) resulting in higher mycosis. Whereas, in wettable powder and crude formulation faster rate of desiccation, inhibits conidia to penetrate the target sight resulting in lesser efficacy. Present findings draw the support from that of Bateman *et al.* (1993), wherein higher mortality of grasshopper in oil based formulation of *M. anisopliae* than aqueous formulation in desert ecosystem. With respect to equipments concerned, the high volume sprayer delivered higher amount of spray solution per unit area, which created congenial micro-climate around the mycopathogen and host as compared to surrounding environment resulted in higher mycosis of *S. litura*. This is in agreement with Lingappa *et al.* (2002), Lingappa and Patil (2002) and Patil *et al.* (2003), who have reported very good control of *S. litura* with spraying of *N. rileyi* using high volume sprayer.

Table 1 Impact of different *N. rileyi* formulations and spray equipments on per cent disease incidence on *S. litura* in groundnut (1st spray)

Treatment	Day before spray				*N. rileyi* incidence on *S. litura* (%)											
					5 DAS				10 DAS				15 DAS			
	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean
F_1	2.3	2.2	2.2	2.23[a]	47.1	41.2	36.4	41.58[a]	47.4	42.1	40.5	43.30[a]	53.1	46.2	46.1	48.46[a]
F_2	2.0	2.3	2.2	2.16[a]	43.6	37.4	32.7	37.88[b]	44.7	40.5	38.6	41.28[b]	50.2	44.7	42.4	45.76[b]
F_3	2.2	2.3	2.0	2.14[a]	41.8	30.4	26.2	32.78[c]	40.7	37.6	39.1	39.13[c]	46.1	42.8	40.6	42.83[c]
F_4	2.3	2.1	2.1	2.15[a]	0.0	0.7	0.6	0.44[e]	1.4	1.1	0.7	1.07[e]	1.6	1.5	1.3	1.45[e]
F_5	2.0	2.0	2.2	2.06[a]	1.1	2.2	2.8	2.00[d]	2.2	2.6	2.0	2.25[d]	3.2	3.7	2.1	2.98[d]
Mean	2.15[a]	2.18[a]	2.12[a]		26.71[a]	22.37[b]	19.73[c]		27.27[a]	24.78[b]	24.17[b]		30.82[a]	27.58[b]	18.48[c]	

Means followed by same alphabet in the column do not differ significantly by DMRT (p = 0.05)
DAS - Days after spraying

F_1 - Oil formulation of *N. rileyi* @ 2 x 10^{11} conidia/ha
F_2 - Wettable powder formulation of *N. rileyi* @ 2 x 10^{11} conidia/ha
F_3 - Crude formulation of *N. rileyi* @ 2 x 10^{11} conidia/ha
F_4 - Recommended package of practice (RPP)
F_5 - Untreated control (UTC)

E_1 - High volume sprayer (Knapsack sprayer)
E_2 - Low volume sprayer (Power sprayer)
E_3 - Ultra low volume sprayer (Battery operated sprayer)

Table 2 Impact of different *N. rileyi* formulations and spray equipments on per cent disease incidence on *S. litura* in groundnut (2nd spray)

Treatment	*N. rileyi* incidence on *S. litura* (%)											
	5 DAS				10 DAS				15 DAS			
	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean
F_1	44.3	42.7	39.7	42.20^a	43.5	40.0	37.3	40.27^a	47.4	43.9	42.5	44.59^a
F_2	43.0	38.9	33.6	38.49^b	40.3	37.2	35.2	37.57^b	44.3	40.1	38.3	40.89^b
F_3	37.3	37.0	32.2	35.48^c	39.4	36.7	34.8	37.06^b	42.5	38.8	35.4	38.89^c
F_4	0.4	0.6	0.9	0.64^e	0.0	0.0	0.0	0.00^d	0.8	0.6	0.6	0.67^e
F_5	2.6	2.3	2.1	2.32^d	4.3	2.6	3.4	3.42^c	3.1	2.4	1.9	2.47^d
Mean	25.50^a	24.28^b	21.69^c		25.54^a	23.32^b	22.13^c		27.62^a	25.15^b	23.73^c	

Means followed by same alphabet in the column do not differ significantly by DMRT ($p = 0.05$)
DAS - Days after spraying

Table 3 Impact of different *N. rileyi* formulations and spray equipments on per cent leaf damage by *S. litura* in groundnut (1st spray)

Treatment	*N. rileyi* incidence on *S. litura* (%)											
	5 DAS				10 DAS				15 DAS			
	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean
F_1	25.2	27.5	30.4	27.70^b	25.4	28.1	30.9	28.14^b	23.2	26.8	31.2	27.07^b
F_2	26.4	27.5	32.8	28.90^b	27.7	29.9	31.4	29.67^{bc}	26.1	28.3	32.6	28.98^c
F_3	27.8	28.9	33.2	29.99^b	29.2	31.4	33.0	31.17^c	30.0	32.7	34.2	32.28^d
F_4	18.1	19.1	19.7	18.96^a	19.3	19.9	20.9	20.00^a	17.3	19.4	21.1	19.27^a
F_5	34.4	36.5	38.4	36.40^c	33.3	35.3	36.4	35.00^d	32.3	34.6	35.6	34.14^e
Mean	26.38^a	27.88^a	30.90^b		26.97^a	28.93^a	30.49^b		25.77^a	28.34^{ab}	30.93^b	

Means followed by same alphabet in the column do not differ significantly by DMRT ($p = 0.05$)
DAS - Days after spraying

Table 4 Impact of different *N. rileyi* formulations and spray equipments on per cent leaf damage by *S. litura* in groundnut (2nd spray)

Treatment	*N. rileyi* incidence on *S. litura* (%)											
	5 DAS				10 DAS				15 DAS			
	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean
F_1	23.6	28.1	30.7	27.46^b	25.3	27.7	29.6	27.52^b	24.7	26.6	30.1	27.10^b
F_2	28.6	31.1	34.2	31.31^c	26.4	29.1	30.7	28.74^{cd}	26.3	27.6	31.2	38.39^c
F_3	30.6	31.7	36.1	32.79^d	27.8	29.8	32.6	30.05^c	27.9	28.4	33.1	29.81^d
F_4	20.2	24.2	23.3	22.58^a	19.2	22.3	23.4	21.64^a	19.5	21.2	22.4	21.02^a
F_5	34.4	36.0	37.2	35.85^e	30.3	32.8	34.6	32.58^e	31.3	33.6	35.2	33.38^e
Mean	27.48^a	30.22^b	32.30^c		25.78^a	28.35^b	30.17^b		25.95^a	27.46^a	30.40^b	

Means followed by same alphabet in the column do not differ significantly by DMRT ($p = 0.05$)
DAS - Days after spraying

Table 5 Effect of different *N. rileyi* formulations and spray equipments on yield of groundnut

Treatment	Yield (q/ha)			
	E_1	E_2	E_3	Mean
F_1	11.68^{b}	10.71^{bc}	9.25^{cde}	10.54
F_2	9.48^{cd}	9.19^{cde}	7.54^{ef}	8.73
F_3	8.46^{def}	8.44^{def}	6.81^{f}	7.90
F_4	13.24^{a}	11.55^{b}	8.35^{def}	11.04
F_5	9.24^{cde}	8.24^{def}	4.86^{g}	7.44
Mean	10.42	9.62	7.36	

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Short communication

Preliminary studies on evaluation of *Nomuraea rileyi* against *Spodoptera litura* (Fabricius) and *Helicoverpa armigera* (Hubner) on groundnut under coastal agro-climatic conditions

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Among the alternatives for chemical insecticides, entomopathogens posses greater potential under selective environmental conditions. These pathogens have narrower spectrum of activity than chemicals but safer to environment. Among the several entomopathogneic fungi, *N. rileyi* is a cosmopolitan species infecting noctuids. It is a likely candidate for development as a microbial insecticide as it occurs naturally in different agro-ecosystems. *Nomuraea rileyi* has been identified as the key mortality factor of many noctuid pests occurring on major crops in northern transitional tract of Karnataka (Lingappa and Patil, 2002). Groundnut area is on the increase in coastal region in residual moisture after rice and in command area as a profitable proposition in *rabil* summer. Development of insecticide resistance in *H. armigera* and *S. litura* has been amply documented by many in general and by Ramegowda and Basavanagoud (2002), receptively in specific in the agroecology under study counteracting the pesticide usage for profitable crop production prompted the search for viable alternate eco-friendly options for insecticides. Among various eco-friendly options, *N. rileyi* holds promise owing to its efficacy in cotton (Hegde, 2001) groundnut and soybean in transitional tract, due to prevalence of favourable ecological features (Lingappa and Patil, 2002). Equally and more important feature of the fungus that makes it as the best candidate is simplicity in its mass production on low cost and easy available substrates like broken rice and sorghum (Hegde, 2001 and Vimaladevi, 1994). Keeping all these comparative advantages in background, investigations were taken to evaluate *N. rileyi* as an alternative tool in the management of *Spodoptera litura* (Fabricus) and *Helicoverpa armigera* (Hubenr) infesting groundnut in coastal agro ecosystem in post rainy seasons.

Field experiments were laid out in farmers fields at Hosagadde (Location - I) and Adighona (Location II) in Ankola taluk, Uttara Kannada district located at 4 and 3 km away from Arabian coast, respectively during 2001-02 and 2002-03 *rabi* / summer. Groundnut (Cv. JL-24) crop raised under residual moisture conditions in rice fallow with 2-3 protective irrigations. *Nomuraea rileyi* was evaluated at three dosages against *S. litura* and *H. armigera* along with one insecticidal treatment and an untreated control. Each treatment was imposed over an area of 200 m^2 at the first location and 300 m^2 at the second location in North - South direction. Each treatment was isolated by 5 m strip to avoid wind drift. First spray was taken up at 40 days after sowing and the second 10 days later. Observations on the larval populations of 3rd instar and above of both the species per metre row were made by shaking the plants a day before and 7 days after each spray. Damage in the new flesh was assessed by visual scores on tender leaves 7 days after each spray.

Pod yield was recorded from each treatment plot and computed to quintals per ha. Data on larval population and foliar damage was subjected to statistical analysis after square root and arc-sin transformations, respectively and the treatment means were separated deploying Duncan's Multiple Range Test (DMRT).

The larval population of *H. armigera* and *S. litura* per meter row before spray ranged from 8.83 to 9.16 during the first year and 7.71 to 8.16 during the second year of study. Irrespective of the locations, N. rileyi proved significantly pathogenic against *H. armigera* and *S. litura* during 2001-02; however, monocrotophos excelled. During the second year and in pooled analysis there existed no difference among the *N. rileyi* treatments and monocrotophos where as, the untreated control performed significantly inferior (Table 1). It is noticed that larval population among the *N. rileyi* treatments failed to differ, but the monocrotophos established superiority by recording lowest larval load of 0.86 larvae/m row. During the second year the larval population was higher after second spray than in the preceding year at the corresponding interval of observation. Pooled analysis of data over two years disclosed at par effectiveness of *N. rileyi* treatments with 1.24 to 1.41 larvae/m row and superiority of monocrotophos. The fungal pathogen was highly effective in reducing larval population as revealed by higher surviving number in untreated control (11.74 larvae/m. row).

After the first spray, during first year higher dose of *N. rileyi* (23.84%) was as good as monocrotophos treatment (17.19%) in reducing damage to leaflets ((Table 2). However, all the doses of *N. rileyi* were on par with each other with percent defoliation ranging from 23.84 to 28.44. During the second year, the results were confirmative except for the lowest dose of *N. rileyi* discriminating as inferior to other dosage levels. Pooled analysis of data over years reiterated the second year performance assessment. Combined analysis of data after second spray for two locations of the year 2001-02 suggest that, all the three doses of *N. rileyi* were equally effective and significantly superior in reducing the leaflet damage (18.44 to 20.63%) over untreated control (54.38), while monocrotophos limited the damage to least (11.88%). The results of the second year and pooled data confirmed the findings of first year.

Yield as reflection of degree of protection offered to the crop by the treatments, reiterated the treatment superiority of monocrotophos with 33.25 q/ha of groundnut pod followed by at par performance of entomopathogen (30.34 to 31.28 q/ha). During 2002-03 the trend remained same but the yield levels were lower. Pooled analysis of the data reveal similar inference of superiority of monocrotophos (33.37 q/ha) followed by microbial pesticide (29.26 to 30.22 q/ha) and inferiority of untreated control (24.2). Impact of protection offered by *N. rileyi* against defoliators was reflected in yield (Table 2).

Table 1 **Effect of *Nomuraea rileyi* spray on the larval population of *Spodoptera litura* and *Helicoverpa armigera* on groundnut in coastal region (Mean of two locations)**

Treatment	Number of larvae / m. row								
	2001-02			2002-03			Pooled		
	BS	7 DAFS	7DASS	BS	7 DAFS	7DASS	BS	7 DAFS	7DASS
N. rileyi @ $2x10^{11}$ conidia/ha	8.88 a	3.20 b	1.73 b	7.87 a	0.30 a	3.05 b	8.38 a	1.75 a	1.41 b
	(3.94)	(2.72)	(2.17)	(3.80)	(1.54)	(2.75)	(3.87)	(2.13)	(2.19)
N. rileyi @ $4x10^{11}$ conidia/ha	9.16 a	3.09 b	1.71 b	8.03 a	0.29 a	3.08 b	8.59 a	1.69 a	1.38 b
	(3.99)	(2.71)	(2.17)	(3.83)	(1.53)	(2.75)	(3.91)	(2.12)	(2.17)
N. rileyi @ $6x10^{11}$ conidia/ha	9.00 a	3.12 b	1.59 b	7.94 a	0.30 a	2.88 b	8.47 a	1.71 a	1.24 b
	(3.96)	(2.73)	(2.10)	(3.81)	(1.54)	(2.69)	(3.88)	(2.14)	(2.11)
Monocrotophos 36 SL @ 0.036%	9.06 a	1.74 a	0.86 a	7.71 a	0.13 a	1.55 a	8.39 a	0.93 a	0.54 a
	(3.97)	(2.31)	(1.79)	(3.77)	(1.35)	(2.24)	(3.87)	(1.83)	(1.73)
Untreated control	8.83 a	9.04 c	11.79 c	8.16 a	6.64 b	11.68 c	8.49 a	7.84 b	11.74 c
	(3.94)	(3.97)	(4.43)	(3.85)	(3.44)	(4.41)	(3.89)	(3.71)	(4.43)
CD (P=0.05)	NS	0.18	0.17	0.20	0.13	0.13	0.05	0.59	0.31
SEm+	0.042	0.06	0.06	0.07	0.05	0.04	0.02	0.21	0.11

Figures in a column followed by same alphabets are statistically indifferent from each other by DMRT at 0.05 probability
* BS -Before spray; 7DAFS - 7 days after 1st spray; 7DASS - 7 days after 2nd spray*
** Figures in parenthesis are root x +1 transformed values

Table 2 **Effect of *Nomuraea rileyi* spray on the new flesh damage by *Spodoptera litura* and *Helicoverpa armigera* and pod yield of groundnut in coastal region (Mean of two locations)**

Treatment	2001-02			2002-03			Pooled		
	NFD (%)		Yield	NFD (%)		Yield	NFD (%)		Yield
	7DAFS	7DASS	Q/ha	7DAFS	7DASS	Q/ha	7DAFS	7DASS	Q/ha
N. rileyi @ $2x10^{11}$ conidia/ha	28.44 b	20.00 b	30.34 b	31.88 c	37.50 b	28.18 b	30.16 c	28.75 b	29.26 b
	(32.10)	(23.36)		(33.96)	(37.63)		(33.03)	(30.49)	
N. rileyi @ $4x10^{11}$ conidia/ha	25.63 b	20.63 b	31.14 b	22.19 b	38.13 b	28.96 b	23.91 b	29.38 b	30.05 b
	(30.17)	(24.01)		(27.75)	(37.98)		(28.96)	(31.00)	
N. rileyi @ $6x10^{11}$ conidia/ha	23.84 ab	18.44 b	31.28 b	24.06 b	34.34 b	29.17 b	23.75 b	26.41 b	30.22 b
	(28.51)	(22.46)		(29.04)	(35.83)		(28.78)	(29.14)	
Monocrotophos 36 SL @ 0.036%	*17.19 a*	*11.88 a*	*33.25 a*	*7.81 a*	*23.13 a*	*33.50 a*	*12.50 a*	*17.50 a*	*33.37 a*
	(24.29)	(16.57)		(15.72)	(28.67)		(20.00)	(22.62)	
Untreated control	58.75 c	54.38 c	25.44 c	61.56 d	86.25 c	22.97 c	60.16 d	70.31 c	24.2 c
	(50.10)	(48.34)		(52.32)	(68.42)		(51.21)	(58.38)	
CD (P=0.05)	4.63	2.92	2.24	4.32	3.92	2.82	3.20	2.34	1.77
SEm+	1.60	1.01	0.77	1.49	1.35	0.97	1.13	0.83	0.63

Figures in a column followed by same alphabets are statistically indifferent from each other by DMRT at 0.05 probability
* BS -Before spray; 7DAFS - 7 days after 1st spray; 7DASS - 7 days after 2nd spray, NFD - New flesh damage
** Figures in parenthesis are angular transformed values

Table 3 Cost effectiveness of *Nomuraea rileyi* spray against *Spodoptera litura* and *Helicoverpa armigera* on groundnut in coastal region

Treatment	Location 1 (Hosagdde)				Location 2 (Adighona)				Mean				
	Yield * (q/ha)	Returns*# (Rs.)	Cost * @ (Rs.)	Benefit cost ratio	Yield * (q/ha)	Returns* (Rs.)	Cost * (Rs.)	Benefit cost ratio	Yield * (q/ha)	Returns* (Rs.)	Cost * (Rs.)	Benefit cost ratio	Total Net Returns (Rs.)
2001-02													
N. rileyi @ $2x10^{11}$ conidia/ha	5.50	8,800	700	12.57	4.30	6,880	700	9.83	4.90	7,840	700	11.20	7,140
N. rileyi @ $4x10^{11}$ conidia/ha	6.50	10,400	1,100	9.45	4.90	7,840	1,100	7.13	5.70	9,120	1,100	8.29	8,020
N. rileyi @ $6x10^{11}$ conidia/ha	6.50	10,400	1,500	6.93	5.17	8,272	1,500	5.51	5.84	9,334	1,500	6.23	7,834,
Monocrotophos 36 SL @ 0.036%	8.50	13,600	520	26.15	7.12	11,392	520	21.91	7.81	12,496	520	24.03	11,976
2002-03													
N. rileyi @ $2x10^{11}$ conidia/ha	6.75	12,150	700	17.36	3.67	6,606	700	9.44	5.21	9,378	700	13.39	8,678
N. rileyi @ $4x10^{11}$ conidia/ha	7.50	13,500	1,100	12.27	4.50	8,100	1,100	7.36	5.99	10,782	1,100	9.80	9,682
N. rileyi @ $6x10^{11}$ conidia/ha	7.75	13,950	1,500	9.30	4.65	8,370	1,500	5.58	6.20	11,160	1,500	7.44	9,660
Monocrotophos 36 SL @ 0.036%	13.00	23,400	520	45.00	8.07	14,526	520	2794	10.53	18,954	520	36.45	18,434
Pooled													
N. rileyi @ $2x10^{11}$ conidia/ha	6.12	10,475	700	14.96	3.98	6,743	700	9.63	5.06	8,609	700	12.30	7,909
N. rileyi @ $4x10^{11}$ conidia/ha	7.00	11,950	1,100	10.86	4.69	7,970	1,100	7.25	5.85	9,951	1,100	9.05	8,851
N. rileyi @ $6x10^{11}$ conidia/ha	7.12	12,175	1,500	8.17	4.91	8,321	1,500	5.55	6.02	10,252	1,500	6.83	8,752
Monocrotophos 36 SL @ 0.036%	10.75	18,500	520	35.58	7.60	12,959	520	24.92	9.17	15,725	520	30.24	15205

* Incremental over untreated check
@ The cost each spray of treatments 1, 2, 3 and 4 are Rs. 350, 550, 750 and 260, respectively.
# The per quintal market value of groundnut pods is Rs. Rs. 1,600 during first year and Rs. 1,800 during second year.

The cost benefit analysis of *N. rileyi* treatments for management of *S. litura* and *H. armigera* is presented in Table 3. It is seen that, as the dosage of *N. rileyi* increased the input cost (plant protection cost) also increased. It was Rs. 700, 1,100 and 1,500 in *N. rileyi* sprays at 2 x 10^{11}, 4 x 10^{11} and 6 x 10^{11} conidia/ha, respectively as against minimum cost (Rs.250) with monocrotophos treatment. As the dosage of *N. rileyi* increased, there was an incremental yield and returns too. Incremental yields as well as returns were highest with monocrotophos and thus it proved to be most cost effective treatment. Among the entomopathogen dosage levels, maximum incremental benefit cost ratio (IBCR) was obtained with lower dose of *N. rileyi* (2 x 10^{11} conidia/ha) and it decreased with increase in dosage despite increase in additional returns.

IBC ratios from pooled analysis for *N. rileyi* treatment were 14.96, 10.86 and 8.17 at location I; 9.63, 7.25 and 5.55 at location II and location averages were 12.30, 9.05 and 6.83 for 2 x 10^{11}, 4 x 10^{11} and 6 x 10^{11} conidia/ha, respectively. In contrast, the IBCR values for monocrotophos treatment were 35.58, 24.92 and 30.24 at Hosagadde, Adighona and mean of both the locations, respectively. Irrespective of the locations, while the trend remained same the incremental net returns were Rs. 7840/-, 9,120/- and 9,334/- during first year, Rs. 9,378/-, 10,782/- and 11,160/- during second year and Rs. 8,609/- 9,951/- and 10,252/- in the pooled data from *N. rileyi* application at the rate of 2 x 10^{11}, 4 x 10^{11} and 6 x 10^{11} conidia/ha, respectively. Though, the IBCR is lowest for higher dosage of microbial pesticide, total net returns were second highest and the most economical treatment proved to be medium dosage of 4 x 10^{11} conidia/ha with the highest net returns during both the years and in pooled analysis. Monocrotophos gave highest net returns of Rs. 11,976/- and Rs. 18,434/- during the first and the second year, respectively and Rs. 15,205/- for the mean.

Increase in yield and returns were more conspicuous between the first two doses of *N. rileyi* than latter two doses (Table 3). There was a linear decline in IBC ratio with increase in fungal dosage and it was only around half of that obtained with lowest dose (2 x 10^{11} conidia/ha) in the case of highest dose (6 x 10^{11}). However, IBC ratio with insecticide spray (monocrotophos) was very high.

Nevertheless, total net returns were highest with the moderate dose (4 x 10^{11} conidia/ha) of *N. rileyi* followed by the highest dose and least with lowest dose without any deleterious effect on entomon fauna and environment. Highest net returns with monocrotophos was due to

highest yield and least additional cost but linked with more environmental hazards.

Results of the present investigations clearly show the potentiality of *N. rileyi* in attenuating the menace of *S. litura* and *H. armigera* on groundnut in coastal region as an option for sustainable and eco-friendly approach in place of toxic insecticide. The pathogen in capable of spreading through self-propelling mechanism due to quick spread of conidia readily. A mild wind can take away the conidia to far off distances and cause mycosis for further spread. Natural incidence on *S. litura* and *H. armigera* in coastal Andhra Pradesh (Sridhar and Devaprasad, 1996 a and b and Manjula *et al.*, 2003) and convincing performance in the present study reiterates the suitability of *N. rileyi* as a cost effective, eco-friendly and sustainable tool for the management of these two defoliators on groundnut in coastal agro-ecosystem.

If we consider the environmental safety, sustainability in production with least disturbance to the coastal and nearby Western Ghats where rich biodiversity is existing, the mycoinsecticide, *N. rileyi* holds greater promise in managing the noctuid defoliators besides conservation of the biodiversity as it is very host specific in its action. Sustainable and low cost management of these two defoliators is possible as *N. rileyi* can cause annual epizootics in nature.

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Short communication

Biology of cabbage butterfly, *Pieris brassicae* (L.) (Lepidoptera : Pieridae) on cabbage and Indian mustard

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Amongst the lepidopterous pests of cruciferous crops, cabbage butterfly, *Pieris brassicae* (L.) (Lepidoptera : Pieridae) has become the most destructive pest throughout the Himalayan ranges including the foot hills and north-eastern hilly states of India (Sachan and Gangawar, 1980; 1990). Losses due to cabbage butterfly have been recorded on increase in Punjab and Haryana. The caterpillars devour the leaves and inflorescence of the crop, while the severe infestation resulted in the complete defoliation of the plants (Jainulabdeen and Prasad, 2004). Since under Pantnagar conditions a tarai region adjoining to foot hill of Shivalic Himalayan range, no literature is available on the biology of this pest, it was thought imperative to study the biology of this pest on cabbage and Indian mustard for sustainable IPM module. The studies wee conducted during March-April, 2006 in BOD at the temperature of 25±1°C and 80-85% relative humidity. Newly hatched larvae were transferred to glass jars with fresh leaf of mustard and cabbage. Each treatment replicated 5 times with 5 larvae in each replication. The duration up to formation of pupa was taken as total larval period. The time elapsing between cessation of feeding by the last instar caterpillar and adult emergence was recorded as the pupal period. The newly emerge adults transferred to a bell jar with a honey solution (10%) soaked cotton swab as a source of food for the moths. The period between the egg laying and the mortality of the adult constituted the total life cycle of one generation.

Egg stage: The eggs were light yellow, elongated in shape, ribbed horizontally as well as vertically and were firmly glued to the under surface or on both side on the leaf in a group of 40-200. Mean incubation period were 3.4 and 3.6 days on cabbage and mustard, respectively (Table 1). Sharma *et al.* (1999) reported 3.6 and 4.7 days incubation period on cabbage and cauliflower, respectively.

Larval stage: The freshly hatched larvae were yellowish green in colour with dark-green bands. They feed gregariously during early instars but disperse out near maturity. Younger larvae scrape the leaf surface while older once consumed the lamina along with the margin and bite holes into leaves leaving in tact the main veins. The larvae underwent four moulting resulting 5 instars was observed. The first instar was completed in 2.6 and 3.6 days on the cabbage and mustard, respectively. The second, third, fourth and fifth instars extend for 2.8, 3, 3 and 3.8 days on cabbage and 4, 3.7, 4, 4.2 days on mustard, respectively (Table 1). Sharma *et al.* (1999) reported this duration was 2.6, 2.9, 2.7, 3.0 and 3.3 days as developmental period for 1st, 2nd, 3rd, 4th and 5th larval instars on cabbage, respectively. Larva completed development in 15.5 and 19.8 days on cabbage and mustard, respectively. Sharma *et al.* (1999) reported this period was 12.4 and 12.5 days for cabbage and cauliflower, respectively. Kamboj and Rana (2005) reported this period 22.4 days on *B. campestris* and 20.5 days on *B. oleracea* var. *capitata* while Aslam and Suleman (1999) observed larval period of 10.25 days.

Pre-pupal and pupal stage: The fully matured caterpillar stopped feeding and pupated on walls of glass jar. The pupa was whitish in colour. The average pre-pupal period was 1.6 and 1.8 days on cabbage and mustard, respectively. Pupal period was recorded 9.4 and 11.4 days on cabbage and mustard, respectively (Table 1). Sharma *et al.* (1999) reported this period as 8.8 and 11.4 days on cabbage and cauliflower, respectively.

Adult: The adult is snow white butterfly having black margin on the wings. Average longevity of the male and the female was 10.3 and 8.3 days on cabbage and 10.8 and 10 days on mustard, respectively (Table 1). Kamboj and Rana (2005) reported that adult male and female longevity was shortest (4.9 and 5.8 days) on *B. campestris* and longest (5.7 and 6.6 days) on *B. oleracea* var. *capitata*. Sharma *et al.* (1999) observed 4.4 and 5.3 days male and female longevity on cabbage, respectively.

Life cycle: The total life cycle was higher (42.8 days male and 44.6 days female) on mustard than slightly short (38.5 and 39.9 days for male and female, respectively) on cabbage (Table 1). Sood *et al.* (1994) reported total life cycle 43.2 days during March-April and 34.2 days during May. The duration of larval, pupal and adult stages of *P. brassicae* was recorded as 10.25, 7.50 and 5.75 days, respectively by Aslam and Suleman (1999). Therefore, results concluded that incubation period of white cabbage butterfly was slightly higher on mustard and total larval period, pupal period and life cycle was higher on mustard.

Thus, the biology of *Pieris brassicae* on cabbage and mustard revealed that except longevity of female adult, all other stages lasted for marginally longer duration on mustard than cabbage.

Table 1 Biology of *P. brassicae* on cabbage and mustard at 25±1°C temperature

Stage	*P. brassicae*			
	Duration (days)			
	Cabbage		Mustard	
	Mean (±)	Range	Mean (±)	Range
Egg	3.4±0.24	3-4	3.6±0.24	3-4
Hatchability (%)	98	95-100	97	95-100
Larva				
I	2.6±0.24	2-3	3.6±0.24	3-4
II	2.6±0.20	2-3	4.0±0.32	3-5
III	3.0±0.32	2-4	3.7±0.20	3-5
IV	3.0±0.32	2-4	4.0±0.32	3-5
V	3.8±0.20	3-4	4.2±0.20	4-5
Total larval period	15.5±0.58	14-17	19.8±0.44	19-21
Pre-pupal period	1.6±0.24	1-2	1.8±0.20	1-2
Pupal period	9.4±0.24	9-10	11.4±0.24	11-12
Adult longevity				
Male	8.98±0.33	8-10	6.5±0.22	6-7
Female	10.3±0.20	10-11	8.3±0.20	8-9
Total life cycle				
Male	38.5±0.86	37-41	42.8±0.64	41-44.5
Female	39.9±1.05	38-43.5	44.8±0.69	43-36

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Short communication

Impact of plant spacing and fertilizer application on linseed and infestation of bud fly, *Dasyneura lini* Barnes

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Cultivation of linseed (*Linum usitatissimum* Linn.) under input stress condition on marginal/ sub-marginal lands by resource poor farmers is a key hole in boosting up its very low productivity (395 kg/ha) at national level. The crop grown under input stress faces a lot of ravages due to biotic and abiotic constraints. Among the biotic factors, bud fly (*Dasyneura lini* Barnes) is the sole pest causing upto 40% yield loss at national level with a range of 17-49% in different linseed growing states (Malik, 2006). Such a high magnitude of yield loss can be managed through insecticides. However, their injudicious application cause deleterious effects on flora and fauna of the linseed eco-system. Hence, it becomes mandatory to search out the alternatives to insecticides for reducing the losses caused by this dreaded pest. Therefore, present studies were conducted to find out the effect of plant spacing and fertilizer application on the crop health and infestation of bud fly.

A field experiment consisting twelve treatments with three replications of 4×3 m plot size was laid out in Factorial Randomized Block Design at the University Farm during 2006-07 on linseed cv Neelum. The treatments consisted combinations of three plant spacing (no thinning, 4 cm and 8 cm apart) and four doses of nutrients ($N_{90}P_{45}K_{30}$, $N_{60}P_{30}K_{20}$, $N_{30}P_{15}K_{10}$ and $N_0P_0K_0$ kg/ha). Plant spacing were maintained at 20 days after sowing of the crop. Full quantity of the fertilizers except half of the nitrogen dose was applied in furrows before seeding and remaining half was given after first irrigation. The crop was raised under irrigated conditions following all recommended agronomic practices except the insect-pests management. Observations on plant height, branches/plant and capsules/plant were recorded at dough stage of the crop, while bud fly infestation was recorded at green bud as well as dough stage on five plants/replication selected randomly. Seed yield was recorded after harvesting of the crop. Thus, the data collected on various aspects were analyzed statistically.

Numbers of branches and capsules/plant were significantly influenced by the plant spacing in linseed. Significantly higher number of branches and capsules/plant were recorded as 7 and 114 in 8 cm distant crop, respectively, as against 5 branches/plant and 86 capsule/plant noticed on without thinning linseed crop (Table 1). However, plant spacing did not significantly affect plant height, bud fly infestation and seed yield, as these parameters ranged 47-51 cm, 37-39% and 1609-1678 kg/ha, respectively.

Table 1 Influence of plant spacing and fertilizer application on yield attributes, bud fly infestation and seed yield in linseed

Factors		Bud fly infestation (%)		Plant height (cm)	Branches/ plant (cm)	Capsule/ plant (No.)	Seed yield (kg/ha)
		Green stage	Dough stage				
Plant spacing (cm)	No thinning	29.1 (32.6)	39.3 (38.8)	51	5	86	1637
	4 cm apart	27.3 (31.5)	37.0 (37.5)	51	6	95	1678
	8 cm apart	27.5 (31.6)	37.3 (37.6)	47	7	114	1609
	SEm±	0.7	0.8	1.5	0.2	7.6	18.9
	CD (P=0.05)	NS	NS	NS	0.7	22.4	NS
Fertilizer application (kg/ha)	$N_{90}P_{45}K_{30}$	30.2 (33.3)	45.4 (42.3)	53	6	118	1876
	$N_{60}P_{30}K_{20}$	28.7 (32.4)	40.3 (39.4)	52	6	106	1822
	$N_{30}P_{15}K_{10}$	26.8 (31.2)	34.9 (36.2)	48	6	92	1677
	$N_0P_0K_0$	26.1 (30.7)	31.3 (34.0)	46	5	78	1190
	SEm±	0.8	1.0	1.7	0.3	8.8	21.8
	CD (P=0.05)	NS	3.0	5.1	0.8	25.8	64.0

Figures in parenthesis are angular transformed values

Application of nutrients (N, P_2O_5 and K_2O) in different doses improved significantly the plant height, pest infestation and seed production of linseed, while numerical variations were observed in bud fly infestation at green bud stage of the crop. The crop grown with highest dose of fertilizer ($N_{90}P_{45}K_{30}$ kg/ha) had significantly maximum plant height, branches/plant and capsules/plant being 53 cm, 6 and 118, respectively, as against the lowest values of 46 cm, 5 and 78 for these characters noticed in without fertilizer application raised crop. However, without fertilizer and lowest dose ($N_{30}P_{15}K_{10}$ kg/ha) of fertilizer applied crop were at par in plant height and number of branches as well as capsules/plant. Bud fly infestation at green bud stage showed only numerical differences (26.1-30.2%) due to fertilizer application, which exhibited significant variations being 31.3-45.4% at dough stage with the enhancement in nutrient application. Significantly highest seed yield being 1876 kg/ha on a par with 1822 kg/ha were harvested from $N_{90}P_{45}K_{30}$ and $N_{60}P_{30}K_{20}$ kg/ha nutrients applied crop, respectively. Lowest seed production (1190 kg/ha) was recorded from the crop grown without fertilizer. Higher dose of fertilizer increased the number of branches with capsules bearing in comparison to without fertilizers applied crop resulting in higher yields, but bud fly infestation was also increased probably due to more availability of flower buds for egg laying. Thus, it can be inferred that plant spacing had insignificant impact on crop growth as well as bud fly infestation, while application of nutrients improved significantly the plants vigour, pest infestation and seed yield in linseed. Literature on the influence of plant spacing on bud fly infestation in linseed is lacking. Higher dose of fertilizers increased the bud fly infestation in linseed as reported by Singh *et al.* (1991) and Malik *et al.* (1996) favoured these studies.

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Short communication

Impact of land configuration and phosphorus management on performance of niger, *Guizota abyssinica* Cass

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In Maharashtra, niger (*Guizotia abyssinica* cass) is not a major oilseed crop, but it is mostly grown as a mixed crop under rainfed condition on variety of soils having low fertility status. Low production of niger is attributed to the fact that the crop is grown in dry farming region, without application of recommended dose of fertilizers. It will be worthwhile to explore the possibility of introducing niger as a sole crop in Marathwada region of Maharashtra under rainfed conditions. The information on suitable land configuration treatments and application of suitable phosphorus level of niger under the edapho-ecological conditions of Marathwada is meager. Therefore, the present investigation was carried out to study the impact of land configuration and phosphorus management on seed yield of niger during *kharif* season.

The experiment was conducted in Randomized Block Design with factorial arrangement having 3 replication during monsoon season of 2006-2007 at Latur, Maharashtra. The main plot treatments were 4 land configurations *viz.*, without opening of furrow (L_1), opening of furrow after two rows (L_2), opening of furrow after four rows (L_3) and opening of furrow after every alternate row (L_4) and sub-plot treatments were 4 phosphorus levels (0, 20, 40 and 60 kg P_2O_5/ha). The experimental unit was 5.4 m x 4.5 m and 4.5 m x 3.6 m in gross and net plot size, respectively. The soil of experimental site was clayey in texture, low in nitrogen (233.24 kg/ha), medium in phosphorus (12.81 kg/ha), high in potassium (612.08 kg/ha) and slightly alkaline in reaction (pH 7.57) crop was sown by dibbling at 30 cm x 10 cm spacing on 1st August, 2006. Full dose of N and treatment wise phosphorus was applied in the experimental plot before sowing. The furrows were opened with spade one month after sowing. Total rainfall of 583.6 mm was received within 24 rainy days.

Treatment (L_4) opening of furrow after every alternate row recorded significantly higher values of all the growth and yield attributes and grain yield kg/ha1 followed by opening of furrow after two rows (L_2), opening of furrows after four rows (L_3) and lowest by without opening of furrow (L_1) (Table 1). Seed yield is a function of yield contributing characters. Hence, increase in seed yield of opening of furrow after every alternate row (L_4) and opening of furrow after two rows (L_2) was due to increase in yield attributes compared with other land configuration treatments i.e., (L_1) without of opening of furrow and opening of furrow after four rows (L_3). This may be attributed due to beneficial effect of moisture conservation in experimental field which was useful for development of more yield attributes/plant. Chaudhari *et al.* (2001) and Jogadande *et al.* (2003) also reported such differential yield of niger. Opening of furrow after every alternate row (L_4) produced significantly the highest grain yield than without opening of furrow (L_1) land configuration and it was at par with opening of furrow after two rows (L_2). Where as, opening of furrows after four rows (L_3) and without opening furrow (L_1) were on par with each other. Oil content was not significantly influenced by land configurations.

Every increase in the level of phosphorus resulted in significant influence on the growth (Table 1) and yield attributes. Increase in seed yield was due to augmenting effect of phosphorus application on all yield attributes since a good supply of phosphorus has been associated with increased root growth, hasten plant maturity and quality of seed. Phosphate compounds have been shown to be essential for photosynthesis, the inter conversions of carbohydrates and related compounds, amino acid metabolism, fat metabolism and sulphur metabolism for oil seed crops. Application of adequate phosphorous results in increased yield and the proportion of oil stored in the seed. Such increase in seed yield of niger was with application of 60 kg P_2O_5/ha and it was on par with application of 40 kg P_2O_5/ha. Lowest seed yield was recorded with application of 0 kg P_2O_5/ha. Similar results were reported by Kachapur *et al.* (1979). Significantly highest oil content of 34.34% was recorded with P_3 (60 kg P_2O_5/ha) which was on par with P_2 (40 kg P_2O_5/ha) phosphorous level followed by P_1 (20 kg P_2O_5/ha) 29.25% and P_0 (0 kg P_2O_5/ha) 28.14% phosphorus level.

The interaction effects were found to be non significant except for oil content .Opening of furrow after four rows (L_3) with application of P_2 (40 kg P_2O_5/ha) recorded significantly higher oil percentage than rest of the treatment combinations. However, it was at par with L_3P_2,

L_2P_3, L_3P_3, L_1P_2 and L_2P_2 treatment combination. L_1P_0 treatment combination recorded significantly the lowest oil percentage. The present study clearly indicated that opening of furrow after every alternate row (L_4) and opening of furrow after two rows (L_2) significantly influenced growth characters, yield and oil content with the application of 40 kg P_2O_5/ha to niger crop.

Table 1 Mean height of plant (cm), number of functional leaves/plant, number of primary branches/plant, number of *capsules/plant, number of grains/capsule, number of grains/plant, test weight (g) and grain yield (kg/ha) of niger as* influenced by land configuration and phosphorus management

Treatment	Mean height of plant (cm)	No. of functional leaves/plant	No. of primary branches/ plant	No. of capsules/ plant	No. of grains/ capsule	No. of grain/ plant	Test weight (g)	Oil content (%)	Grain yield (kg/ha)
***Land configuration* (L)**									
L_1 : Without opening of furrow	69	19	9	32	23	425	3.0	30.9	293
L_2 : *Opening of furrow after two rows*	73	25	10	39	27	517	4.0	31.4	338
L_3 : Opening of furrow after four rows	71	21	9	34	5	467	3.2	31.0	296
L_4 : *Opening of furrow after alternate rows*	74	26	11	42	28	551	4.0	31.4	341
SEm±	1.6	0.7	0.1	0.6	1.0	40	0.05	0.4	12.8
CD (P=0.05)	4.8	2.2	0.7	1.9	3.0	116	0.34	NS	37.4
Phosphorus levels (P)									
P_0 : 0 kg P_2O_5/ha	69	16	8	30	23	458	2.8	28	279
P_1 : 20 kg P_2O_5/ha	71	18	9	33	25	465	3.1	29	295
P_2 : 40 kg P_2O_5/ha	71	25	10	37	26	501	4.0	33	337
P_3 : 60 kg P_2O_5/ha	75	27	10	39	28	538	4.1	34	357
SEm±	1.6	0.7	0.2	0.6	1.0	40	0.01	0.4	12.9
CD (P=0.05)	4.8	2.2	0.7	1.9	3.0	116	0.34	1.3	37.4
Interaction (L x P)									
SEm±	3.3	1.5	0.5	1.0	2.0	80	0.24	0.9	25.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	4.6	NS
General mean	71.8	22.1	9.3	35.8	26.0	490	3.94	31.2	316.9

Table 2 Oil content (%) in grain of niger as influenced by land configurations x phosphorus levels

Treatment	P_0	P_1	P_2	P_3
L_1	26.2	31.6	33.6	27.7
L_2	30.3	27.8	32.6	35.0
L_3	28.4	29.3	36.1	30.4
L_3	27.7	28.3	35.2	34.4
SEm ±	0.45			
CD (P=0.05)	1.36			

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Short communication

Assessment of various ecofriendly strategies for management of *Alternaria* blight in Indian mustard, *Brassica juncea* (L.) Czern and Coss

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Indian mustard is an important edible oilseed in India and is grown annually on about 6.5 m. ha. A major factor limiting its productivity is *Alternaria* blight. Yield losses may vary from 10 to 70% depending on the type of crop species grown and prevailing environmental conditions; maximum (>70%) being in yellow *sarson* and *toria* and low to moderately high (35-40%) in mustard (Kolte, 1996). In the absence of a proven source of resistance (Kolte, 2005), the disease is currently managed by selective application of fungicides (Chattopadhyay and Bagchi, 1994). With the advent of alternative methods of plant disease control, biocontrol agents and botanicals have emerged as important components of integrated disease management (Meena *et al.*, 2004). Such toxic fungicides however, contaminate ground water and enter food chain, thereby impacting a range of organisms. Consumers perception worldwide now is that chemical usage in agricultural production needs to be significantly reduced (Matteson, 1995). In order to satisfy this demand, biocontrol strategies are being looked into. Such an information, however is very limited for managing *Alternaria* blight. The present study was thus undertaken to assess the potential of a few non-toxic measures for *Alternaria* blight management in Indian mustard.

The experiment was conducted on *B. juncea*, with bioagent, *Trichoderma harzianum* @ 1 x 10^5 spores/ml, *Pseudomonas fluorescence* @ 1 x 10^8 cfu/ml; plant extract, eucalyptus (*Eucalyptus globosus*) leaves @ 5% (w/v), garlic (*Allium sativum*) bulb @ 2% (w/v); non toxic chemicals, zinc sulphate @ 0.2%, borax @ 0.5%, calcium sulphate @ 0.5%, soil application of potash @ 40 kg/ha and sulphur @ 20 kg/ha; recommended fungicide, mancozeb @ 0.2% active ingredient.

Experiment was conducted in Randomized Block Design with three replications over two years. Plot size was 4.0 m x 3.0 m with a row-to-row spacing of 30 cm x 15 cm. Spray solution for non-toxic chemicals *viz.*, zinc sulphate @ 0.2%, borax (0.5%) and calcium sulphate (0.5%) of required concentration were prepared from their salts. *Trichoderma harzianum* was grown in autoclaved potato dextrose broth in 250 ml Erlenmeyer flasks after inoculating with Potato Dextrose Agar disc for its active fungal growth and incubated for 10 days at 23 ± 1°C. The fungal growth with the spores was harvested from the broth and churned in waring blender with required amount of sterile distilled water to get spore suspension containing 1 x 10^5 spores per ml. *Pseudomonas fluorescence* was cultured on 100 ml King's B broth medium in 250 ml Erlenmeyer flasks. These were incubated at 28°±C on shaker at 120 rpm for 48 hrs. Sprays of formulations having concentration of 1 x 10^8 of cfu/ml were made. For preparation of plant extracts fresh leaf samples of eucalyptus and garlic bulbs were collected and washed with tap water and sterile distilled water. These were then processed with sterile water @ 1 ml/g of tissue (1:1 w/v) in a waring blender and filtered through a double layered cheese cloth. This formed the standard plant extract solution (100%). The extracts were subjected to low speed centrifugation and clear supernatants were collected. The required concentrations were prepared using this stock solution. Application of potash and sulphur was carried out as basal dose at the time of sowing. Based on active ingredient, spray solution of mancozeb was prepared. Untreated control was maintained. Foliar sprays were applied 45 and 75 days after sowing. *Alternaria* blight was recorded on leaves and pods using pictorial scale (Conn *et al.*, 1990). Seed yield was recorded at maturity in each treatment.

All the treatments resulted in significant (P>0.05) disease reduction on leaves and pods over the diseased control (Table 1). *Alternaria* blight severity on leaves and pods following mancozeb application was 47.7 and 44.6%, respectively. Among the other treatments, *Trichoderma harzianum* caused 22.1 and 21.5% reduction of *Alternaria* blight on leaves and pods respectively. The efficacy of *T. harzianum* for reducing the disease could be due to its capacity to use food-source more efficiently than the *A. brassicae*, there by crowding it out or its products discourages or kill *A. brassicae* (Monte, 2001). It was followed by *P. fluorescence* and zinc sulphate with the reduction in the disease by 19.6 and 16.0% of leaves. Zinc sulphate appeared more effective on the pods with a disease reduction of 18.9% as compared to 18.2% following application of *P. fluorescence*. It has been previously reported (Kaur *et al.*, 2002) that antagonistic

micro-organisms including *Trichoderma harzianum* may induce host resistance against *Alternaria* or reduce pathogen infestation (Sivapalan, 1993). Varying level of reduction in disease severity on leaves and pods was also observed for garlic bulb extract (16.1/18.2%) and calcium sulphate (12.9/13.9%). *Alternaria* blight control achieved following application of garlic bulb extract was however, significantly lower than that reported by Meena *et al.* (2004), who reported excellent *Alternaria* blight control by garlic extract which was at par with the disease reduction following mancozeb application.

Summarizing, present investigation indicated enhanced yield realization following various disease control strategies as compared to untreated control. Highest increase of 45.6% in yield over unprotected control was observed in treatment with mancozeb, which was almost at par with that achieved following *T. harzianum* application. This was followed by zinc sulphate with 34.8% increase in yield. *P. fluorescence* and calcium sulphate recorded 32.9, 28.7% increase in seed yield. Garlic bulb extract also appeared promising with 27.7% increase in yield. Thus present study indicated the efficacy of new *Alternaria* blight management strategies in comparison to current fungicides. However, the results on botanicals and biocontrol agents require further investigations, especially in relation to their mode of action against the target pathogen.

Table 1 *Alternaria* blight severity and its management by using alternative strategies in mustard

Treatment	Mean per cent severity of *Alternaria* blight on leaves 90 DAS*			Mean per cent severity of *Alternaria* blight on pods 1WBM**			Yield (kg/ha)		
	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean
Trichoderma harzianum	64.5	33.5	49.0	63.5	32.1	47.8	370	500	4.3
Pseudomonas fluorescence @ 1%	67.0	34.2	50.6	66.0	33.6	49.8	340	480	4.1
Eucalyptus globosus @ 5%	68.2	39.9	54.0	66.0	38.7	52.3	340	420	3.8
Garlic bulb extract @ 2%	69.0	36.6	52.8	64.4	35.2	49.8	360	450	4.1
Zinc sulphate @ 0.2%	70.2	35.5	52.8	64.3	34.5	49.4	360	470	4.1
Borax @ 0.5%	73.2	43.8	58.5	60.2	42.0	51.1	330	310	3.2
Calcium sulphate @ 0.5%	72.2	37.5	54.8	68.4	36.5	52.4	350	440	3.9
Mancozeb @ 0.2%	63.0	32.4	47.7	59.2	30.0	44.6	380	510	4.5
Soil application of Potash 40 kg + Sulphur 20 kg/ha	67.0	38.6	52.8	68.3	37.4	52.8	340	430	3.8
Control	78.4	47.5	62.9	75.0	46.8	60.9	330	290	3.1
CD (P=0.05)	0.45	0.80	0.50	0.67	0.32	1.53	NS	80	NS

* Days after sowing; ** Week before maturity

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Short communication

Population dynamics of sesamum gall fly, *Asphondylia sesami* Felt. and its correlation with abiotic factors

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Til, *Sesamum indicum* L. is a major oilseed crop in India. The infestation of insect pests is one of the main constraints for its low production. The crop is attacked by more than 38 species of insect pests at various crop stages of growth. Of these gallfly, *Asphondylia sesami* Felt. is a regular occurring pest in North-Saurashtra region of Gujarat state. The pest feed within the flower buds and transforms them into galls that produce no seeds.

Field trials were conducted during *kharif*, 1995 to 2006 (sowing could not be done during 1998 and 1999 due to drought conditions) at Millet Research Station, Junagadh Agricultural University, Jamnagar on a non-replicated observation plot of about 150 m^2 area was sown with sesame variety, Gujarat Til-1.

The recommended agronomical package of practices of the crop cultivation were followed. No insecticide was applied to this area. Observations on the incidence of gallfly were recorded from 50 randomly selected plants by counting healthy as well as galls formed due to gallfly infestation at weekly interval. Observations were started from the initiation of flowering and continued up to maturity of the crop. Finally, gallfly infestation (%) was worked out. Weather data were taken from the Meteorological Department and were correlated with various weather parameters by using simple correlation coefficient.

The incidence of gallfly was observed during all the ten years (Table 1). The range of infestation of gallfly was found low i.e., 2.84-8.65% (2000); 0.29-4.08% (2005) and 4.05-5.00% (2006). While in the remaining years, its incidence was found very high i.e., 5.89-29.70 (1995) to 10.87-80.49% (1997). Mean of percent gallfly incidence indicated that incidence started from 35 days after sowing (3.7%), i.e., initiation of the flowering (Table 2). The incidence was found to increase gradually and reached to its peak i.e. 31.8 % at 70 DAS. But after that it declined toward maturity of the crop i.e., 18.4 %. Bharodia (1997) reported the pod damage by gallfly from first week of September and the highest pod damage was recorded in second week of September at Junagadh.

The gallfly infestation was significantly positively correlated with maximum temperature and difference between maximum and minimum temperature (Table 3).

Table 1 Yearwise incidence of gall fly, *Asphondylia sesami* along with weather parameters during 1995 to 2006

Standard week	Year	Per cent gall fly incidence									
		1995	1996	1997	2000	2001	2002	2003	2004	2005	2006
	Date of sowing	21.07.95	25.06.96	04.07.97	07.07.00	07.07.01	28.06.02	04.07.03	03.08.04	29.06.05	09.07.06
	Rainfall (mm) during crop period	60	171	196	482	168	0	649	28	575	545
	Rainy days	3	11	10	12	10	0	16	2	13	17
27	02-08 July	-	0.0	-	0.0	-	-	-	-	0.0	-
28	09-15	-	0.0	-	0.0	-	-	-	-	0.0	-
29	16-22	-	0.0	0.0	0.0	0.0	-	-	-	0.0	-
30	23-29	-	0.0	0.0	0.0	0.0	-	0.0	-	0.0	-
31	30-05 August	-	12.4	0.0	0.0	0.0	-	0.0	-	0.0	0.0
32	06-12	-	12.6	10.9	0.0	0.0	-	0.0	-	3.3	0.0
33	13-19	-	33.6	30.9	2.8	18.8	-	0.0	-	4.1	0.0
34	20-26	0.0	33.5	38.0	4.0	38.2	-	10.8	-	2.7	0.0
35	27-02 September	0.0	40.2	70.0	5.0	50.1	-	16.6	0.0	0.7	4.1
36	03-09	5.9	21.4	80.5	8.0	54.6	0.0	19.7	0.0	0.3	5.0
37	10-16	8.8	-	-	8.7	55.5	0.0	28.6	15.3	-	4.1
38	17-23	23.2	-	-	6.9	54.8	0.0	48.1	25.3	-	-
39	24-30	29.7	-	-	-	57.9	0.0	-	36.5	-	-
40	01-07 October	27.9	-	-	-	-	18.1	-	40.0	-	-
41	08-14	26.0	-	-	-	-	18.8	-	51.0	-	-
42	15-21	-	-	-	-	-	36.2	-	-	-	-
43	22-28	-	-	-	-	-	33.1	-	-	-	-
	Range (Min - Max)	5.9-29.7	12.4-40.2	10.9-80.5	2.8-8.7	18.8-57.9	18.1-36.2	10.9-48.1	15.3-51.0	0.3-4.1	4.1-5.0

During 1998 and 1999, sowing could not be done

Table 2 Crop stage wise incidence of sesamum gallfly, *Asphondylia sesami* during 1995 to 2006

Crop stage (days after sowing)	Gallfly incidence (%)										
	1995	1996	1997	2000	2001	2002	2003	2004	2005	2006	Mean
28 DAS	0	0	0	0	0	0	0	0	0	0	0.0
35 DAS	0	0	0	0	18.8	18.1	0	0	0	0	3.7
42 DAS	5.9	12.4	10.9	2.8	38.2	18.8	0	15.3	3.3	4.0	11.2
49 DAS	8.8	12.6	30.9	4.0	50.1	36.2	10.9	25.3	4.1	5.0	19.4
56 DAS	23.2	33.6	38.0	5.0	54.6	33.1	16.6	36.5	2.7	4.1	25.9
63 DAS	29.7	33.5	70.0	8.0	55.5	0	19.7	40.0	0.7	0	27.8
70 DAS	27.9	40.2	80.5	8.7	54.8	0	28.6	51.0	0.3	0	31.8
77 DAS	26.0	21.4	0	6.9	57.9	0	48.1	0	0	0	18.4

Table 3 Correlation coefficient relationship between sesamum gallfly and weather parameters

Year	Temp. Maxi.	Temp. Mini.	Diff. of Mini. & Maxi Temp.	RH Morn (%)	RH Even (%)	Rainfall (mm)	Rainy days
1995 (n=8)	0.5500	(-)0.8800**	0.8101*	(-)0.3102	(-)0.6781	0.2562	0.2193
1996 (n=10)	(-)0.7061*	(-)0.7208*	(-)0.2821	0.1604	0.3094	(-)0.4243	(-)0.5205
1997 (n=8)	0.0580	(-)0.1185	0.1111	(-)0.1711	(-)0.7994*	(-)0.1462	(-)0.1208
2000 (n=12)	(-)0.0268	(-)0.7905**	0.5937*	(-)0.7099**	(-)0.6518*	(-)0.4426	(-)0.4890
2001 (n=11)	0.8250**	0.1418	0.3743	(-)0.2712	(-)0.8460**	(-)0.6159*	(-)0.5896
2002 (n=8)	0.8489**	(-)0.9071**	0.9494**	(-)0.8588**	(-)0.8764**	99.9990	99.9990
2003 (n=9)	0.7146*	(-)0.7684*	0.6218	(-)0.8428**	(-)0.8878*	(-)0.5430	(-)0.6698*
2004 (n=7)	0.5838	0.0947	0.4407	0.2578	(-)0.0293	0.2748	0.2748
2005 (n=10)	(-)0.0728	(-)0.6439*	0.4729	0.0003	(-)0.2683	(-)0.3478	(-)0.4224
2006 (n=7)	0.8216*	0.3269	0.8819**	(-)0.6593	(-)0.8753**	(-)0.6260	(-)0.7823*
Overall (n=90)	0.2475*	(-)0.1272	0.2163*	(-)0.1163	(-)0.3296*	(-)0.2627*	(-)0.2812*

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

It clearly indicated that maximum temperature plays an important role for population buildup of sesamum gallfly. Incidence of gallfly increased as the day temperature increased. Difference of maximum and minimum temperature also found to play an important role in gallfly buildup. Its correlation with incidence of gallfly was found significantly positive, which clearly indicated that its incidence increased while minimum temperature at night decreased simultaneously day time maximum temperature increased. While with evening relative humidity, rainfall and rainy days it showed significantly negative correlation, which indicated that with high relative humidity at evening and high rainfall distributed in more numbers of rainy days, affected adversely on the activity of sesamum gallfly. Remaining weather parameters *viz.*, minimum temperature and morning relative humidity showed negative correlation with gallfly infestation but it was found statistically non significant. Bharodia (1997) found that maximum temperature had significant and positive correlation with infestation of gallfly, while evening relative humidity, rainfall and rainy days adversely affected the pest infestation under Junagadh conditions. Rakholia (2001) also reported positive correlation with maximum temperature. While, it showed significant and negative correlation with minimum temperature and morning and evening relative humidity. Thus, the present findings and in confirmation with the earlier reports.

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Short communication

Field screening of extant varieties of sesame, *Sesamum indicum* L. against powdery mildew disease

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Sesame (*Sesamum indicum* L.) is the important edible *kharif* oilseed crop. The productivity of sesame has been stagnating over the years due to many factors, of which susceptibility of the crop to different diseases is one of the major factors. Powdery mildew caused by *Erysiphae orantii* Cast (Rajpurohit, 1993) is the important disease of sesame, occurring widely throughout India and causes substantial qualitative and quantitative loss to the crop. Although different fungi have been reported from different parts of the country as casual organisms of the disease *viz.*, *Erysiphe cichoracearum* DC (Hirata, 1966; Krishnaswami *et al.*, 1984; Ganesh *et al.*, 1992), *Sphaerotheca fuliginea* (Gemawat and Verma, 1972), *Oidium* sp. (Mehta, 1951) and *Leveillula taurica* (Patel *et al.*, 1949). Various fungicides have been recommended for controlling the disease incidence. Nevertheless, the direct use of sesame for food is increasing and indiscriminate use of chemicals, particularly on food crops like sesame will be hazardous and detrimental for its export. The use of resistant varieties is the most effective, economically safe and practical means of controlling this disease. In the present investigation efforts were made to identify powdery mildew resistant varieties, under field conditions.

The material consisted of 68 genotypes representing 65 varieties developed by different centres of National Agriculture Research System and released for commercial cultivation in different parts of the country and three local varieties grown by the farmers. All the varieties were grown at experimental field of J.N. Agricultural University, Jabalpur on 16th July, 2004 and 13th August 2005, in a five row plot (3.0 x 2.0 m) and replicated twice. The observations on powdery mildew severity were recorded after 70 days of sowing. Randomly selected 20 plants in each variety were scored for per cent leaf/plant area covered by powdery mildew lesions in a 0-5 scale (0=No infection, 1=1 to 10% leaf/plant area infected, 2=11 to 25% leaf/plant area infected, 3=26 to 50% leaf/plant area infected, 4=51 to 70% leaf/plant area infected, 5=71 to 100% leaf/plant area infected).

Powdery mildew appeared around one month old crop and subsequently the incidence become severe during capsule formation stage. The average score of 20 plants of both the years in each variety was taken and the results are depicted in Table 1.

Out of 68 varieties of sesame screened during 2004 and 2005 under field conditions to study level of resistance/tolerance to powdery mildew infection, only three varieties i.e., N-8, Paiyur-1 and E-8 showed highly resistant reaction, 22 varieties *viz.*, VS-9701, SVPR-1, Guj. Til-1, Guj. Til-10, Rajeshwari, Krishna, DS-1, HT-1 Thilathara, RT-103, TMV-3, TMV-4, Co-1, AKT-101, MT-75, Phule Til-1, Thilak, VRI-1, Kayamkulam-1, B-67, Vinayak, JLT-7 showed resistant reaction, 24 varieties viz; T-12, T-13, Swetha Thil, TC-289, TMV-5, TMV-6, Guj. Til-2, Thilarani, Thilothama, Chandana, T-78, TKG-55, Shekhar, YLM-11, YLM-17, PB Til-1 ORM-17, AKT-64, RT-127, Madhvi, Purva-1, JTS-8, JT-7, Local Chaupala showed moderately resistant reaction with level of infection ranging from 11 to 25 %. However, remaining varieties were moderately susceptible to susceptible against powdery mildew infection. None of the variety was highly susceptible to the disease. Krishnaswami *et al.* (1984) found 184 genotypes to be resistant to *E. cichoracearum*. Natarajan *et al.* (1983) also reported 5 cultures, out of 57 lines of sesame to be highly resistant to *E. cichoracearum*. Varieties Co.1, T-13, TMV-3 and TC-289 were also reported to be resistant to powdery mildew over two or more seasons by other workers also (Vyas *et al.*, 1983).

The use of resistant varieties has been strongly advocated for the integrated disease management in crop plants. On the basis of screening, resistant varieties such as N-8, paiyur-1 and E-8 are recommended in areas where powdery mildew appears in severe form to sustain sesame productivity.

Powdery mildew (*Erysiphae orantii* Cast (Rajpurohit, 1993) is an important disease of sesame (*Sesamum indicum* L.), causing substantial damage to the crop throughout India. Screening of 68 genotypes of sesame representing 65 officially released varieties and three local varieties done at JNKVV Jabalpur Farm, during two *kharif* seasons in 2004-05 and 2005-06 under field conditions revealed that three varieties (N-8, Paiyur-1 and E-8) exhibited highly resistant reaction and 22 varieties (VS-9701, SVPR-1, Guj. Til-1, Guj. Til-10, Rajeshwari, Krishna, DS-1, HT-1

Thilathara, RT-103, TMV-3, TMV-4, Co-1, AKT-101, MT-75, Phule Til-1, Thilak, VRI-1, Kayamkulam-1, B-67, Vinayak and JLT-7) as resistant reaction to powdery mildew on 0-5 scale. On the basis of screening, resistant varieties such as N-8, paiyur-1 and E-8 are recommended for inclusion in the integrated management of disease, particularly in the central India where powdery mildew appears in severe form for sustaining the productivity of sesame.

Table 1 Reaction of sesame varieties to powdery mildew disease during *kharif*

Scale	Reaction	No. of varieties	Name of variety
0	Highly Resistant	3	N-8, Paiyur-1 and E-8
1	Resistant	22	VS-9701, SVPR-1, Guj. Til-1, Guj. Til-10, Rajeshwari, Krishna, DS-1, HT-1 Thilathara, RT-103, TMV-3, TMV-4, Co-1, AKT-101, MT-75, Phule Til-1, Thilak, VRI-1, Kayamkulam-1, B-67, Vinayak, JLT-7
2	Moderately Resistant	24	T-12, T-13, Swetha Thil, TC-289, TMV-5, TMV-6, Guj. Til-2, Thilarani, Thilothama, Chandana, T-78, TKG-55, Shekhar, YLM-11, YLM-17, PB Til-1 ORM-17, AKT-64, RT-127, Madhvi, Purva-1, JTS-8, JT-7, Local Chaupala.
3	Moderately Susceptible	14	Kanak, RT-54, TKG-21, TKG-22, Rama, JLT-26, T-4, Usha, Uma, OS-Sel-164, PKDS-11, PKDS-12, Brijeshwari, RT-46.
4	Susceptible	5	Kalika, RT-125, TC-25, Kapli, Adarsh-8.

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Short communication

Response of nutrient application on bud fly and gram pod borer infestation in linseed, *Linum usitatissimum* L.

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Linseed (*Linum usitatissimum* L.) faces biotic and abiotic stresses resulting in poor productivity at national level in comparison to global level. Among biotic factors, bud fly (*Dasyneura lini* Barnes) is the key pest causing economic yield losses to this crop, but gram pod borer (*Helicoverpa armigera* Hubner) is also responsible for heavy crop losses in certain linseed growing regions (Patnaik and Lenka, 2000; Malik, 2000). However, these pests can successfully be managed through chemicals. Balanced use of different nutrients is a boon for the vertical expansion in productivity level of this crop owing to better crop vigour, which may withstand the biotic stresses. Keeping in view the deleterious effects of insecticides recommended for the management of these insect pests, impact of nutrient application on these pests and yield in linseed was assessed.

Twelve treatment combination of different inputs *viz.*, T_1 100% recommended dose of fertilizer (RDF) i.e., $N_{80}P_{40}$ kg/ha; T_2-75% RDF+5 t/ha FYM+5kg/ha zinc (zinc sulphate) + 25 kg/ha sulphur + bio-fertilizer (*Azotobacter* + PSB); T_3-75% RDF + 5 kg/ha zinc + 25 kg/ha sulphur + bio-fertilizer; T_4-75% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur; T_5-75% RDF + 5 t/ha FYM; T_6-75% RDF; T_7-50% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur + bio-fertilizer; T_8-50% RDF + 5 kg/ha zinc + 25 kg/ha sulphur + bio-fertilizer; T_9-50% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur; T_{10}-50% RDF + 5 t/ha FYM; T_{11}-50% RDF and T_{12}-farmers practice were replicated thrice in Randomized Block Design to observe their effect on bud fly as well as gram pod borer infestation and seed yield. Infestation of insect-pests was recorded at dough stage of the crop on 10 randomly selected plants/replication and yield at harvest, which were computed for their critical differences. Economics of the treatments was also analyzed.

Significantly lowest bud fly infestation being 33.9% was recorded on the crop grown under 50% RDF + 5 kg/ha zinc + 25 kg/ha sulphur + biofertilizer (T_8), which was at par with 34.5, 35.7 and 35.9% bud infestation received in 50% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg sulphur + biofertilizer (T_7), 75% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur (T_4) and 50% RDF + 5 t/ha FYM (T_{10}), respectively. However, linseed grown as per farmers practice and 100% RDF only had significantly superior bud infestation of 42.7% on both the treatments. Linseed crop sown with 100%, 75%, 50% RDF and farmers practices harboured 42.7%, 35.7-40.7%, 33.9-36.4% and 42.7% bud fly infestation, respectively. These infestation range in different fertilizer doses exhibited that crop raised with higher fertilizer level was more prone to bud fly than the low concentration. Enhancement in bud infestation with increased dose of fertilizer in linseed is in accordance with Malik *et al.* (1996). Significantly maximum capsule infestation being 7.7% was recorded in farmers practice followed by 7.1, 6.8 and 6.6% capsule infestation in 50% RDF + 5 kg/ha zinc + 25 kg/ha sulphur + biofertilizer (T_7), 100% RDF (T_1) and 50% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur applied crop (T_9), respectively. Statistically lowest capsule infestation being 5.6% was observed in 75% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur (T_4), which did not differ significantly from 6.8 and 7.1% capsule infestation received in 100% RDF (T_1) and 50% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur + biofertilizer (T_7), respectively. Application of 100%, 75% and 50% RDF had a decreasing trend being 6.8, 6.2 and 5.7% capsule infestation by gram pod borer. However, addition of other nutrients did exhibit a zig-zag pattern of the pest damage. Available literature on this aspect in linseed is silent, however application of phosphatic fertilizer reduce the gram pod borer infestation in Chickpea (Prasad *et al.*, 1985). Significantly higher seed yield of 1456 kg/ha was obtained from linseed crop applied 75% RDF with all other nutrients (T_2), which was at par with 1350, 1331 and 1312 kg/ha received from T_4, T_1 and T_5 treatments, respectively (Table 1). The treatment (T_2) provided maximum net monetary of Rs. 12608/ha with 2.41 as incremental benefit cost ratio. However, incremental net monetary returns in other treatments ranged between Rs. 5904 to 10912/ha. It can be inferred that cultivation of linseed with 75% fertilizer + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur + bio-fertilizer (T_2) proved the most beneficial. Better economic return from fertilizer applied linseed crop is in conformity with Malik *et al.* (1997). It can be concluded that application of 75% recommended dose of fertilizer along with FYM (5 t/ha),

zinc (5 kg/ha), sulphur (25 kg/ha) and bio-fertilizer (*Azotobacter* + PSB) superseded the seed production (1456 kg/ha) with highest incremental net monetary return (Rs. 12608/ha) and benefit : cost ratio (2.41) due to better crop vigour, which had 37.9 and 6.0% moderate infestation of bud fly and gram pod borer, respectively. Linseed crop sown as per farmers practice produced lower yield with higher infestation of insect pests.

Table 1 Effect of nutrient application on insect pests infestation and their economics in linseed

Treatment	Insect pests infestation		Economics				
	Bud fly infestation (%)	Gram pod borer infestation (%)	Seed yield (kg/ha)	Cost of treatment (Rs/ha)	Gross monetary return (Rs/ha)	Incremental net monetary return (Rs/ha)	Incremental B:C ratio
T_1	42.7 (40.78)	6.8 (15.07)	1331	4360	21296	10608	2.43
T_2	37.9 (37.96)	6.0 (14.18)	1456	5220	23296	12608	2.41
T_3	40.7 (39.64)	6.4 (14.64)	1268	4160	20288	9600	2.31
T_4	35.7 (36.69)	5.6 (13.73)	1350	5170	21600	10912	2.11
T_5	38.7 (38.49)	5.7 (13.76)	1312	4720	20992	10304	2.18
T_6	39.9 (39.17)	6.2 (14.38)	1250	3660	20000	9312	2.54
T_7	34.5 (35.89)	7.1 (15.41)	1238	4320	20288	9600	2.22
T_8	33.9 (35.83)	6.4 (14.61)	1143	3260	18288	7600	2.33
T_9	35.1 (38.34)	6.6 (14.81)	1114	4270	18304	7616	1.78
T_{10}	35.9 (36.80)	6.3 (14.58)	1100	3820	17600	6912	1.81
T_{11}	36.4 (37.11)	5.7 (13.74)	1037	2760	16592	5904	2.14
T_{12}	42.7 (40.78)	7.7 (18.14)	668	-	10688	-	-
SEm ±	0.55	0.57	83				
CD (P = 0.05)	1.14	1.18	172				

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Short communication

Efficacy of newer insecticides against safflower aphid, *Uroleucon compositae* T.

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Safflower (*Carthamus tinctorius* L.) is one of the major drought tolerant winter season oilseeds crop of the world. In India, Safflower is grown on residual soil moisture over an area of about 4 lakh ha with annual production of 2.20 lakh tonnes. The major safflower growing states include Maharashtra and Karnataka. Maharashtra has the largest area (65 %) under safflower with an area of 2.5 lakh ha with a production of 1.20 lakh tonnes and productivity of 477 kg/ha. The safflower oil has an important commercial and medicinal value. Although 101 insect pests have been recorded on safflower throughout the world of which safflower aphid (*Uroleucon compositae* T.) is one of the major pests. Control of safflower aphid has been achieved by using different insecticides (Neharkar *et al.*, 2003). This unilateral approach has provided an effective but short term remedy. Efforts were, therefore, made in the present investigation to evaluate the efficacy of some of the newly developed insecticides from different groups in comparison with dimethoate for the control of safflower aphid.

The effectiveness of some new insecticides were tested for their efficacy against safflower aphid (*U. compositae* T.) during *rabi* seasons in 2004-05 and 2005-06 at AICRP (Safflower), Solapur(Table 1). The field experiments were conducted using cv. Bhima in Randomized Block Design with 9 treatments, 3 replications in a plot size of 5.0 x 4.5 m^2 each. Two need based foliar sprays were given at an interval of 15 days during each season. The observations on aphid count (5 cm apical twig/plant) were recorded on three randomly selected plants in each treatment before and after sprays. Pre count was taken a day prior to the treatment. The data on surviving aphids/plant before and after treatment were subjected to pooled statistical analysis by transforming average count to the arcsine values.

Table 1 Efficacy of newer insecticides against safflower aphid (2004-05 and 2005-06)

Treatment	First spray : Av. Aphids/5 cm twig/plant						Second spray : Av. Aphids/5 cm twig/plant			Grain yield (kg/ha)		B:C ratio	
	Before spray			After spray									
	04-05	05-06	Mean	04-05	05-06	Mean	04-05	05-06	Mean	04-05	05-06	04-05	05-06
Imidachloprid @ 0.0045%	53.7	74.7	64.7	05.0	25.9	15.4	03.3	07.5	05.4	462	1079	1.4	2.4
	(47.1)	(59.9)	(53.5)	(11.9)	(30.6)	(21.2)	(08.2)	(15.8)	(12.0)				
Acetamiprid @ 0.004%	56.3	71.0	63.7	01.7	23.1	12.4	01.3	06.5	03.9	576	1204	1.6	2.5
	(48.6)	(57.4)	(53.0)	(05.9)	(28.7)	(17.3)	(03.9)	(14.6)	(9.2)				
Thiamethoxam @ 0.005%	59.3	72.7	66.0	00.3	19.3	09.8	02.3	05.5	03.9	702	1413	2.0	3.0
	(50.4)	(58.5)	(54.5)	(01.9)	(26.1)	(14.0)	(07.0)	(13.4)	(10.2)				
Fipronil @ 0.01%	57.0	73.3	65.2	27.3	53.9	40.7	12.3	27.2	19.8	364	529	1.0	1.0
	(49.0)	(59.0)	(54.0)	(31.4)	(47.2)	(39.3)	(20.5)	(31.4)	(25.9)				
Abamectin @ 0.0009%	53.7	75.0	64.3	37.7	50.8	44.2	26.0	31.0	28.5	307	566	0.6	0.9
	(47.1)	(60.1)	(53.6)	(37.8)	(45.4)	(41.6)	(30.7)	(33.8)	(32.2)				
Difenthiuron @ 0.06%	51.7	75.7	63.7	29.5	61.7	45.6	10.3	38.3	24.3	318	395	0.6	0.6
	(46.0)	(60.5)	(53.2)	(32.8)	(51.8)	(42.3)	(18.7)	(38.3)	(28.5)				
Buprofexin @ 0.04%	59.0	72.7	65.8	40.7	64.2	52.4	35.0	41.8	38.4	285	409	0.8	0.9
	(50.2)	(57.5)	(53.8)	(39.6)	(53.3)	(46.4)	(36.3)	(40.3)	(38.3)				
Dimethoate @ 0.03%	58.3	77.7	68.0	07.2	34.5	20.8	04.0	15.0	09.5	547	1125	1.8	2.8
	(49.8)	(61.8)	(55.8)	(15.2)	(35.9)	(25.6)	(11.3)	(22.8)	(17.0)				
Control	56.0	75.0	65.5	59.0	93.7	76.3	61.3	83.8	72.6	132	181	1.5	0.5
	(48.5)	(60.1)	(54.3)	(50.2)	(77.3)	(64.0)	(51.6)	(67.5)	(59.5)				
SEm ±	01.9	02.4	02.6	03.2	03.1	07.3	03.7	02.8	06.6	76	168	-	-
CD(P=0.05%)	NS	NS	NS	06.7	06.6	16.9	07.9	06.0	15.2	161	356	-	-
CV (%)	04.8	06.3	-	15.3	08.6	-	21.9	11.2	-	23	27	-	-

(Figures in parentheses are arc-sine transformed values)

The results reveled the significant differences among treatments in respect of both aphid population after each spray and seed yield at harvest in both years. However, aphid population recorded before first spray was statistically non significant which indicated the uniformity in pest population (Table 1). All the treatments were significantly superior in the control of aphid, however, thiamethoxam (0.005%), acetamiprid (0.004%) and imidachloprid (0.0045%) registered lower aphid population than the recommended dimethoate (0.03%) after both the sprays during both the seasons. These three treatments were at par with one another in each of the individual year and on the basis of pooled data as well. The highest decline in aphid population over control after two sprays during both the years has recorded with thiamethoxam (87.1 and 94.6%) followed by acetamiprid (83.8 and 94.6%), imidachloprid (79.8 and 92.6%), dimethoate (72.7 and 86.9%) and fipronil (46.7and 72.8%). The pooled mean seed yield for two years of safflower varied from 157 to 1057 kg/h. However, the yield level during 2004-05 was lower than that of 2005-06 due to scanty rainfall. Thiamethoxam yielded significantly higher than control. From remaining treatments the maximum seed yield was recorded from acetamiprid followed by dimethoate and imidachloprid. The highest B:C ratio (2.5) was obtained in thiamethoxam followed by dimethoate (2.3), acetamiprid (2.1) and imidachloprid (1.9). Rest of the treatments were economically ineffective. It indicated that the spraying of thiamethoxam or acetamiprid is beneficial for management of safflower aphid as well as for increasing the seed yield of safflower under dry land conditions. The lowest B:C ratio (0.5) was observed in control, indicating the importance of aphid management through such newer insecticides having different chemical class and novel mode of actions to develop an ecologically sound IPM modules. The results of present investigation in respect of effectiveness and compatibility of thiamethoxam when used as seed dresser for sucking pests are in agreement with Satpute *et al.*, (2002) and Prasanna *et al.*, (2002).

Overall results concluded that the spraying of thiamethoxam or acetamiprid at 40 and 55 days after sowing is beneficial for the management of aphid and increasing the seed yield of safflower.

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Short communication

Cultural characters of stem rot, *Sclerotium rolfsii* isolates of groundnut from red and black soils of Anantapur district of Andhra Pradesh*

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Groundnut is a major oilseed crop which constitutes about 80% of total cropped area (0.8 million ha) under rainfed conditions during *kharif* season in Anantapur district of Andhra Pradesh. About 86% of the area is covered with red soils, 13.9% by black soils and 0.1% problematic soils which are spread in three revenue divisions *viz.*, Anantapur, Dharmavaram and Penugonda of Anantapur district. Monocropping of groundnut both in *kharif* and *rabi* seasons is in vogue.

Anantapur district experiences frequent dry spells ranging from 21 to 50 days and is characterized by low annual rainfall of 552 mm and falls under semiarid tropics. TMV2 (local) is the most popular groundnut variety followed by JL-24 and Vemana in both red and black soils of district. The major production constrains are unreliable and erratic distribution of rainfall and appearance of unpredictable diseases and pests accounting low productivity (750 kg/ha) of groundnut. Diseases are one of the major factors responsible for this. Late leaf spot (LLS) caused by *Phaeoisariopsis personata* (Berk. and Curt.) V. Arx., Stem and bud necrosis and stem rot caused by *Sclerotium rolfsii* Sacco are economically important diseases in Anantapur district.

Stem rot of groundnut caused by *S. rolfsii* has attained the status of priority disease next to late leaf spot due to its serious nature in recent years in Anantapur district of Andhra Pradesh. The disease incidence and yield losses due to stem rot has gradually increased from 10 to 45% during the years 1994 to 1997 (Annual Progress Report, Agricultural Research Station, Anantapur, 1997).

The occurrence of the disease is more visible at the time of harvest during *kharif* season under rainfed situations due to low and erratic distribution of rainfall. The disease incidence was increasing every year due to mono cropping of the groundnut. In addition, farmers are not taking adequate measures to control late leaf spot disease after 75 DAS, which has direct correlation in perpetuation of *S. rolfsii*. The vulnerable stage of the disease coupled with intermittent rains resulted in heavy pod loss. Although pronounced variability in morphological characteristics of various *S. rolfsii* isolates is well documented (Punja, 1985), there are only few reports of differences in pathogencity and virulence of isolates from various hosts (Cooper, 1961). Recent studies have confirmed that *S. rolfsii* isolates may vary considerably in their ability to colonize groundnut plants (Shokes, F.M. and Brenneman, T.B., Unpublished). Host specialization has not yet been demonstrated. However, the incidence of stem rot was more severe in red soils than black soils. Hence the present study was undertaken to study the cultural and morphological characteristics of various isolates of *S. rolfsii* collected each from red and black soils of three revenue divisions of Anantapur district.

Groundnut plants showing stem rot symptoms were collected from red and black soils of three divisions (Table 1). From the infected stem portion of diseased plants, the adhering soil particles and other debris were removed by thorough washing under running tap water. After that, the infected stem portions were cut into small bits of 1 cm size and were surface sterilized by immersing in 0.1% mercuric chloride for 30 seconds. The bits were washed in three changes of sterile water to remove traces of mercuric chloride and blotted dry on clean, sterile paper towels. These cut pieces were aseptically transferred to PDA petriplates and incubated at 28±2°C temperature for 3 to 4 days. Fungal growth emerging from diseased stem bits was transferred directly on the medium with the help of sterilized needle. The pathogen isolated from red and black soils were designated as *Sclerotium rolfsii* - Red and black soil isolates.

Twenty millilitre of autoclaved and cooled medium was poured in to 90 mm petriplate and allowed to solidify at room temperature. Later mycelial disc of (5 mm) different *S. rolfsii* isolates were cut with the help of sterilized cork borer from the edge of three days old culture to the center of each petriplates. Four replications were maintained for each isolate and the petriplates were incubated at 28 ±

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2°C. For determining the variation among different isolates of *S. rolfsii* in colony growth, the colony growth of the fungus in each petriplate was measured when the fungus in some of the plates covered entire petriplate. Observation on radial growth was recorded after every 24 hr. The colony growth was measured along two diameters at right angles and averaged. For each isolate of *S. rolfsii*, observations for various cultural and morphological characteristics like colour, number, size of sclerotia and their arrangement on solid medium was recorded 15 days after inoculation. The mature sclerotia in each petriplate were harvested separately using fine camel brush and counted. The data obtained were subjected to analysis.

Six isolates of *S. rolfsii* were obtained from red and black soils of Anantapur, Dharmavaram and Penugonda divisions of Anantapur district and were grown on PDA medium at room (28 ± 2°C) temperature (*S. rolfsii* Sr1 (Ananatapur- Red), *S. rolfsii* Sr2 (Ananatapur- Black), *S. rolfsii* Sr3 (Dharmavaram- Red), *S. rolfsii* Sr4 (Dharmavaram - Black), *S. rolfsii* Sr5 (Penugonda- Red) and *S. rolfsii* Sr6 (Penugonda- Black). The existence of variation among the isolates was studied based on the cultural and morphological characters like colony growth, sclerotial number, colour and arrangement of sclerotia.

From each revenue division one isolate each from red and black soils were isolated. A significant variation was noticed among the six isolates of *S. rolfsii* with respect to colony growth on PDA medium. The colony growth of six isolates is presented in Table 2. Among the isolates, Sr1 recorded maximum colony diameter (90 mm) after 64 hr and is significantly superior to all other isolates followed by Sr5 isolate with 85.70 mm diameter. Minimum growth of 81.20 mm was observed in Sr 6 isolate and was on par with Sr3 isolate (82.05 mm), Sr2 isolate (81.78 mm) and Sr4 isolate (81.40 mm). The pH of the red soils in these divisions varied from 6.75 to 7.35 where as it varied from 8.10 to 8.26 in black soils. While the EC of both red and black soils in the three revenue divisions varied from 0.15 to 0.26 and 0.18 to 0.31 dS/m respectively (Table 2).

Azhar Hussain *et al.* (2003) reported that *S. rolfsii* can survive at pH from 5-8 indicating the survival ability at different pH levels under *in vitro* conditions but it was maximum at pH 6.0. The growth of the fungus decreased by increasing pH level as reported by several workers. The results are in agreement with Watkins (1961), Subramanian (1964), Prasad *et al.* (1986), Singh and Gandhi (1991), Shim and Starr (1997), Kulkarni *et al.* (1998), Rangaswami and Mahadevan (1999), Gupta *et al.* (2002), and Palaiah and Adiver (2003), who reported that the growth occurs over a wide range of pH from 2 to 9 and the optimum being 6.0 as the pH increased correspondingly the mycelial growth and sclerotial formation decreased.

Sclerotial count was done after 15 days of inoculation. The Sr1 isolate produced maximum number of sclerotia (310) followed by Sr5 (297), Sr2 (296). While Sr 3, Sr 6 and Sr4 isolates produced 289, 248 and 233 sclerotia, respectively (Table 2).

Table 1 Groundnut plants showing stem rot symptoms collected from red and black soils of three divisions

Name of the location/village		Variety	Soil type	Age of the crop (days)	pH	EC
Anantapur Division	Kothapalli	TMV2	Black soil	80 and at harvest	8.10	0.28
	Reddipalli	TMV2	Red soil	80 and at harvest	7.20	0.20
	Rotaripuram	TMV2	Red soil	80 and at harvest	7.18	0.20
	Ananthapur	TMV2	Red soil	80 and at harvest	7.15	0.20
Dharmavaram Division	Dharmavaram	TMV2	Red soil	80 and at harvest	7.23	0.22
	Tadimarri	TMV2	Red soil	80 and at harvest	6.80	0.20
	C.K. palli	TMV2	Red soil	80 and at harvest	6.75	0.20
	Kanaganapalli	TMV2	Red soil	80 and at harvest	7.30	0.14
	Ramagiri	TMV2	Red soil	80 and at harvest	7.35	0.26
	Bathalapalli	TMV2	Black soil	80 and at harvest	7.20	0.18
Penugonda Division	Madakasira	TMV2	Red soil	80 and at harvest	7.30	0.20
	Penugonda	TMV2 TMV2	Red soil Black soil	80 and at harvest 80 and at harvest	7.30 8.26	0.15 0.31
	Puttaparthi	TMV2	Black soil	80 and at harvest	7.20	0.18

Table 2 Cultural characteristics of *S. rolfsii* isolates on PDA medium

Isolate	Colony characters	Radial growth after 64 hr (mm)	Number of sclerotia/plate
Sr1	Colony growth was loosely arranged in radiating manner. Sclerotia are brown to dark brown. Spread all over the medium	90.00	310
Sr2	Colony growth was thick, white, sclerotia are brown to dark brown, mostly round, concentrated in the periphery of the medium	81.78	296
Sr3	Colony growth was thick, white, Sclerotia light brown to brown, oval to round. Spread all over the medium	82.05	289
Sr4	Mycelial growth was loosely arranged. Sclerotia light brown to dark brown. Oval to round, concentrated in the periphery of the medium	81.48	233
Sr5	Colony growth was loosely arranged in radiating manner. Sclerotia brown to dark brown, spread all over the medium, mostly round. Spread all over the medium	85.70	297
Sr6	*Colony growth was loosely arranged in radiating manner. Sclerotia are brown to dark brown, oval to round spread all over the medium*	*81.20*	*248*
SEm±		0.51	6.52
CD (P=0.05)		1.53	19.64

In Anantapur district the water holding capacity of red soil was very less compared to black soils resulting poor water holding capacity coupled with high soil temperature ranging from 25 to 33°C favored the growth of the fungus. The present study was supported by Mishra and Bias (1986) who observed highest plant mortality caused by *S. rolfsii* in sandy, coarse and sandy loam soils than loam and clay soils. According to Kulkarni *et al.* (1998) the optimum soil moisture level for saprophytic survival was 30% moisture holding capacity, with a decrease in survival as soil moisture level increased, which was in agreement with the findings of Subramanian (1964), Palakshappa *et al.* (1989) and Saxena and Khare (1994). The present study, showed that the high incidence of stem rot in red soils may due to prevalence of optimum favorable weather conditions like high temperature, poor water holding capacity, pH (7.35), EC (0.31 dS/m) and soil moisture (40%) than in black soils. Among six isolates, Sr1 (Anantapur - red soil isolate) recorded maximum colony diameter (90.0 mm)with in 64 hr and more number of sclerotial bodies (310) after 15 days of inoculation.

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Short communication

Interrelationship between mustard aphid, *Lipaphis erysimi* (Kalt.) population and biochemical constituents of oilseed *Brassicas*

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A large number of insect pests are found associated with oilseed *Brassica* crops in India of which the mustard aphid, *Lipaphis erysimi* (Kalt.) is most important (Rohilla *et al.*, 1987). The availability of resistance sources has been greatly emphasized all over the world as one of the most appropriate tool of the Integrated Pest Management (IPM) of major insect pests. Singh *et al.* (1983) reported that high amount of sinigrin (glucosinolate) in indigenous and exotic *Brassica juncea* genotypes was responsible for their resistance to the mustard aphid. Therefore, seven genotypes of *Brassica* species were raised under protected v/s unprotected sets sown in Randomized Block Design with three replications during 2002 through 2004. The aphid population was recorded from top 10 cm portion of the central shoot of each of the 10 randomly selected plants from each genotype. The seed yield was also recorded to work out the yield loss. Samples of top 10 cm portion of inflorescence of central shoot were collected and analysed for various biochemical constituents by using the method of Swain and Hills (1959) (total phenols), Balabaa *et al.* (1974) (Flavonoids) and Thies (1982) (glucosinolates).

The pooled analysis of data over three years revealed that the aphid population recorded from top 10 cm portion of central shoot ranged from 7.4 to 83.6 nymphs and adults on different genotypes (Table 1). Significantly lowest population was recorded on T-27 (*Eruca sativa*) and higher on purple mutant (*Brassica juncea*). Significantly lowest concentration of phenoles was recorded in purple mutant as compared to T-27 but it was on a par with other five genotypes.

There was a significant negative correlation coefficients r=-0.907, -0.732, -0.955 and -0.967 with aphid population on various genotypes. As the phenolic content in the inflorescence increased the aphid population on various genotypes. As the phenolic content in the inflorescence increased the aphid population decreased. Similar relationship was also observed between aphid population and glucosinolate content inflorescence and aphid populations. Ahuja *et al.* (1999) also reported inverse relationship between aphid population and isothiocyanates. High concentration of total phenols and glucosinolates are responsible for imparting resistance to mustard aphid in oilseed *Brassicas*. Higher amount of sugars, phenols, flavonoids and glucosinolates are inversely related to the aphid population and its biological parameters in the screen-house, thus, provided antibiosis against mustard aphid (Bakhetia *et al.*, 1995 and Chander *et al.*, 1997).

Table 1 Aphid population and biochemical constituents in top 10 cms inflorescence part of plants of different genotypes of rapeseed-mustard (Pooled analysis of three years)

Brassica sp.	Genotypes	Aphid population/plant	Total phenols mg/g dry weight tissue	Flavonols mg/g dry weight tissue	Glucosinolate s μ ml/g dry weight tissue
B. juncea	RK 9501	62.0 (7.4)	8.3	2.5	53.3
	Purple mutant	83.6 (8.6)	7.8	3.0	57.2
	RH 9501	66.5 (7.8)	8.6	3.0	58.9
	RH 7846	59.5 (7.2)	8.5	2.6	61.1
	JMM 927	64.4 (7.4)	8.6	2.5	54.7
B carinata	DLSC-2	35.1 (5.5)	9.3	3.1	84.4
Eruca sativa	T-27	7.4 (2.7)	11.2	3.6	94.9
CD (P=0.05)	-	(2.1)	1.1	0.7	23.9

Figures in parenthesis are root n+1 transformations.

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Short communication

Impact of improved technology on the productivity of Indian mustard

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Edible Oilseed crops are an important part of Indian agriculture and contribute more than 10% to agriculture GDP. India is second largest producer of oilseeds in the world. Indian mustard [*Brassica juncea* (L.) Czern & Coss] is the major oilseed grown in Uttar Pradesh during *rabi* season. In U.P., the area under cultivation of this crop is around 5.97 lakh ha with annual production of 5.84 lakh metric tonnes. The average productivity of U.P. (9.79 q/ha) is very low as against the world productivity (15.11 q/ha). The reasons for low productivity are due to poor insect-pests management, lack of improved varieties and use of imbalanced fertilizers. Among the insect-pests, mustard aphid (*Lipaphis erysimi* (Kalt)) causes yield loss ranged from 35.4 to 91.3% and is the most serious pest (Singh and Sachan, 1994). Therefore to see the impact of improved technologies on mustard crop, a series of Front Line Demonstrations (FLDs) were conducted at farmers' fields starting from 1996 through 2001 in the district of Muzaffarnagar, U.P. Four technologies *viz.*, improved variety Bio-902 (Pusa Jai Kisan), aphid management by early sowing (up to 15th October) and one spray of endosulfan 35EC@1.5 l/ha at evening hours and disease (Alternaria blight and rust) management by seed treatment with Metalaxyl @ 1.5 g/kg seed and one spray of dithane M-45 @ 2.5 kg/ha at 50 days after sowing and fertilizers application @120 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha + 200 kg gypsum/ha. Half dose of nitrogen + 40 kg P_2O_5 + 40 kg K_2O + 200 kg gypsum was given at sowing time and remaining 60 kg N was used at 30 days after sowing along with farmers practices through 120 FLDs.

Table 1 Productivity potentials and economics of technologies in mustard, *Brassica juncea* (L.) Czern & Coss

Treatment	No. of demonstrations	Year	Av. Yield (kg/ha)		Increase in yield over farmers' practice		Cost (Rs/ha)		Net profit (Rs/ha)	Cost benefit ratio
			Improved technological intervention	Farmer practice	%	kg/ha	Increased yield	Improved technology		
T_1	50	1996-97 1997-98	2023	1531	32.1	492	5166	350	4816	14.8
T_2	25	1998-99	1984	1478	34.2	506	7084	550	6534	12.9
T_3	11	1999-00	1615	1529	5.6	86	1053	750	303	1.4
T_4	34	2000-01	1912	1537	24.4	375	4875	2350	2525	2.1

T_1: Variety Bio-902 (Pusa Jai Kisan); T_2: Aphid management by early sowing (up to 15th October) and one spray of endosulfan 35EC@1.5 l/ha; T_3: Disease (*Alternaria* blight and rust) management by seed treatment with Metalaxyl @1.5g/kg seed and one spray of dithane M-45 @2.5kg/ha at 50 days after sowing; T_4: Fertilizers application @120 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha + 200 kg gypsum/ha (60 kg N+40 kg P_2O_5+40 kg K_2O+200 kg gypsum was used at sowing time and remaining 60 kg N was used 30 days after sowing)

The results revealed that aphid management had on edge over rest of the technologies with highest increase in grain yield (34.2%) followed by use of improved variety, fertilizers management and disease management with an increase of 32.1, 24.4 and 5.6%, respectively. The maximum net return was obtained with aphid management (Rs 6534/ha) followed by use of improved variety (Rs. 4816/ha), fertilizers management (Rs. 2525/ha) and diseases management (Rs. 303.5/ha), whereas use of improved variety had highest cost benefit ratio (14.8) followed by aphid management (12.9), fertilizer management (2.1) and diseases management (1.4), respectively. The findings revealed that a gap exists between the actual farmer's yield and realizable yield potential of the variety. Mustard aphid management and use of improved variety carry potential to enhance the present level of mustard productivity which is not percolating down at desired pace due to lack of confidence among the farmers. Hence, to exploit the potential of improved production and protection technologies efforts through FLDs ought to be increased considerably to create awareness among the farmers.

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GUIDELINES TO THE CONTRIBUTORS

The contributions in the form of full papers and short communications, based on original research relating to basic and applied aspects of oilseed crops in the disciplines of Genetics and Plant Breeding, Biotechnology, Agronomy, Entomology, Plant Pathology, Crop Physiology, Soil Sciences, Chemistry, Biochemistry, Economics and Extension including post-harvest technology will be considered for publication in the **Journal of Oilseeds Research** only from members of the ISOR. The reviews on current topics and recent books will also be published. The articles submitted for publication must not contain data older than 5 years on the date of receipt of the article in the society office. The period shall be reckoned from the following January and July after the completion of the field experimentation in *kharif* and *rabi* seasons, respectively.

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Book : **Trenbath, T. 1986.** Resource use by intercrops. In *Multiple Cropping Systems* (ed. Charles A. Francis). Macmillan Publishing Company, New York.

Chapter : **Hanumantha Rao, C. and Chakrabarthy, S.K. 1997.** Castor. In *Efficient management of dryland crops: Oilseeds* pp.257-272 (eds. R.P. Singh, P.S. Reddy and V. Kiresur) Indian Society of Oilseeds Research, Hyderabad.

Thesis : **Satyanarayana, K.V. 2000.** *Genetic analysis of elite inbred lines using L x T design and modified* TTC model in sunflower (*Helianthus annuus* L.). M.Sc. (Ag.) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.

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