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Genetic improvement in Spanish type groundnut, *Arachis hypogaea* L. varieties in India over the years

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Abstract

Groundnut area in India has increased gradually from 2.6 m.ha in the early 1930s to nearly 8.0 m.ha in the early 1990s and the production from 2.5 m. tonnes to around 7.5 m. tonnes during the same period. Though a number of niche-specific varieties have been released coupled with development of suitable improved production technologies, the improvement in average productivity is not quite visible. In order to assess the genetic improvement in Spanish type groundnut varieties, which occupy more than 50% of groundnut area in India, a field study was conducted for two seasons under irrigated conditions using 49 varieties released during 1905-2002, and the increments in pod and kernel yields and component traits over the years were studied. An annual increase of 9.4 kg/ha in pod yield and 6.2 kg/ha in kernel yield was observed. The trend in improvement was greater with 24.1 kg/ha pod yield increase when the pod yield in the best variety released during each decade of development was analysed. The enhanced pod yield has resulted mainly from improvement in number of pods/plant, pod and seed weight. Improvement in shelling and sound mature kernel percentage was not significant. Availability of sufficient variability in the germplasm for quality traits, pest resistance, drought tolerance, etc., should enable the breeders to incorporate these traits into breeding programmes and develop varieties endowed with higher yield potential in future.

Key words: *Arachis hypogaea*, genetic improvement, Spanish groundnut

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops in India, occupying and contributing nearly 30% of the total area and production of oilseeds in the country. India stands first in terms of area (7.5 m.ha) among more than 100 countries where groundnut is grown, with a share of around 20% (7.8 m. tonnes) in the world production, next only to China (FAO, 2007). The productivity level of groundnut in India is far below the world average of 1400 kg/ha mainly because it is predominantly grown as a rainfed crop (80% of the total acreage) under various biotic and abiotic constraints that limit crop yield.

It is believed that groundnut was introduced into India in the first half of 16th century by the Spaniards (Krapovickas, 1968). Purposeful introduction of improved varieties of groundnut in India was made towards the end of 19th century. In 1884, the Mauritius variety was introduced to Pondicherry and Madras from Mauritius. During 1901-02, the Bombay Department of Agriculture introduced Pondicherry groundnut Mauritius from Madras, Spanish and Virginia from America, and Small Japan and Large Japan from Japan. New introductions fared better than the local cultivars and the area under cultivation began to increase rapidly. Three of these cultivars gradually spread over the various parts of the country with variant names *viz.*, Peanuts, Spanish Peanuts (variants of Spanish), Coromandal, Mauritius, Mozambique (variants of Mauritius), and Bold (variant of Big Japan) and formed the basis for groundnut improvement and research in India (Seshadri, 1962). The first improved variety, Spanish Improved, a pure-line selection from Spanish groundnut, was released in 1905 from Dharwad of Karnataka State. From 1906 to 1960, nearly 16 varieties were released that were developed either through mass-selection or pure-line selection from the local and introduced varieties. A special umbrella project, All India Coordinated Research Project on Oilseeds (AICORPO) was established during 1967 to address the research needs of improving the production and productivity of nine oilseed crops including groundnut. Special emphasis on groundnut research was laid with the establishment of the National Research Centre for Groundnut (NRCG) in 1979 at Junagadh, Gujarat. Groundnut improvement was further strengthened through a mission mode approach with the launching of Technological Mission on Oilseeds (TMOP) in May 1986. Groundnut was delineated from the AICORPO and was given a separate project status as 'All India Coordinated Research Project on Groundnut' during 1992. Increased momentum in groundnut varietal development programmes has resulted in the release of more than 130

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groundnut varieties belonging to different habit groups. At present, the Spanish type groundnut occupies more than 50% of the groundnut area in India. The main Spanish type groundnut growing states are Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu. In the present paper, an attempt has been made to highlight the genetic improvement achieved over the years in yield and related traits in Spanish type groundnut varieties developed in India since the release of the first improved variety, Spanish Improved.

Materials and methods

Field evaluation of 49 Spanish type varieties (Table 1) was conducted at the National Research Centre for Groundnut (presently Directorate of Groundnut Research), Junagadh (70.36°E longitude and 21.31°N latitude, 60 m above MSL) in the summer seasons of 2002 and 2004 under assured irrigation and management. The evaluation trial was laid out in a Completely Randomised Block Design with three replications.

Table 1 Name, pedigree, origin, year of release and mean performance of 49 Spanish groundnut varieties

Name	Pedigree	Place of origin	Year of release	Mean performance (kg/ha)	
				Pod	Kernel
Sp. Improved	Selection from Spanish Peanut	Dharwad	1905	904	574
AK 12-24	Selection from a local variety	Akola	1940	1034	728
TMV 2	Mass Selection from Gudhitham Bunch	Tindivanam	1940	1047	693
J 11	Ah 4218 x Ah 4354	Junagadh	1964	1121	795
SB XI	Ah 4218 x Ah 4354	Jalgaon	1965	1184	789
TMV 7	Selection from Tenesse White	Tindivanam	1967	794	490
S 206	Selection from Manvi Local	Raichur	1969	1068	660
Jyothi	Selection from Exotic 7	Khargone	1971	1200	733
DH 3-30	Spanish Improved x US 4	Dharwad	1975	757	417
MH 1	Selection from Faizpur 1-5	Hissar	1975	888	551
JL 24	Selection from EC 94943	Jalgaon	1978	620	376
TMV 12	Pure line selection from Ugandan culture	Tindivanam	1978	1124	730
CO 1	Ah 6279 x TMV 3	Coimbatore	1979	1061	720
Kisan	Spanish Improved x B 31	Chiplima	1980	1111	737
KRG 1	Selection from Argentina	Raichur	1981	1138	743
TG 17	Dark Green Mutant x TG 1	Trombay	1982	1040	644
CO 2	EMS mutant of Pollachi 1	Coimbatore	1983	1126	697
GG 2	J 11 x EC 16659	Junagadh	1983	1654	1112
Jawan	J 11 x Asiriya Mwitunde	Chiplima	1983	1011	645
DH 8	Selection from RS 144	Dharwad	1984	843	518
TG 3	Mutant of Spanish Improved	Trombay	1985	1146	713
ICGS 11	Selection from Robut 33-1	Hyderabad	1986	1242	803
SG 84	Selection from ICGS 1	Ludhiana	1986	1397	885
Girnar 1	X 14-4-B-19-B x NCAc 17090	Junagadh	1988	1676	981
ICGS 44	Selection from Robut 33-1	Hyderabad	1988	1498	923
VRI 2	JL 24 x CO 2	Vriddhachalam	1988	980	606
RG 141	Robut 33-1 x NCAc 2821	Durgapura	1989	1844	1248
Tirupati 1	Selection from EC 106983/3-1	Tirupati	1989	1320	929
ICG (FDRS) 10	Ah 65 x NCAc17090	Hyderabad	1990	1238	695
ICGS 1	Selection from Robut 33-1	Hyderabad	1990	1326	911
VRI 3	J 11 x Robut 33-1	Vriddhachalam	1990	1308	914
GG 3	GAUG 1 x JL 24	Junagadh	1991	1143	783
ICGV 86590	X 14-4-B-19-B x PI259747	Hyderabad	1991	1499	884
TAG 24	TGS 2 (TG 18 x M 13) x TGE 1	Trombay	1991	2335	1569
Tirupati 2	GAUG 1 x NCAcFLA-14	Tirupati	1991	1337	928
TG 22	Robut 33-1 x TG-17	Trombay	1992	1529	987
GG 4	CGC 3 x Chico	Junagadh	1993	1622	1081
K 134	Kadiri 3 x JL 24	Kadiri	1993	1772	1156
TKG 19A	TG 17 x TG 1	Trombay	1993	1112	703
TG 26	BARCG 1 x TG 23	Trombay	1995	1703	1104
Tirupati 4	JL 24 x Ah 316/S	Tirupati	1995	1027	654
GG 5	27-5-1 x JL 24	Junagadh	1996	1219	807
ALR 2	Selection from ICGV 86011	Aliyarnagar	1997	1416	979
Kadiri 4	Dh 3-30 x NCAc 2230	Kadiri	1997	1807	1237
R 9251	JL 24 x TG 23	Raichur	1997	1562	1048
GG 6	CGC 3 x FESR-5-P6-B1-B1	Junagadh	1999	1561	1106
JL 220	JL 80 x VG 77	Jalgaon	1999	1190	737
GG 7	S 206 x FESR 8	Junagadh	2001	1917	1250
AK 159	JL 24 x CGC 4018	Akola	2002	1487	916
CD (P=0.05)				631	429

Individual plots were two rows, 3 m long and 90 cm wide with a row-to-row distance of 45 cm. Plant-to-plant distance of 10 cm was maintained within a row. The soil type of experimental site was medium black and calcareous. The varieties were grown following the recommended production practices (25 kg N/ha and 50 kg P_2O_5/ha as basal dose) for the Saurashtra region of Gujarat. At maturity, 10 plants were selected at random from each replication and observations on pod and kernel yields and related traits were recorded. Pod yield was also recorded on net plot basis and expressed in kg/ha. Observations on shelling outturn, 100-pod weight (HPW), 100-seed weight (HSW) and sound mature kernel (SMK) percentage were recorded from the bulk of the randomly selected plants in each variety and replication.

Statistical analysis: Analyses of variance were conducted for each season and over the seasons. The mean values for different traits of the varieties grouped according to decade of release were plotted to obtain the general trend over the years. Linear regressions of pod yield of 49 varieties and that of the best variety for each decade were worked out to determine the trends in yield and value attributable to genetic improvement. Yield advantage in the best variety of each decade over a high yielding variety released prior to 1960 was calculated. Genetic improvement in yield component traits over the years was also calculated.

Results and discussion

Analysis of variance indicated significant differences among the varieties for all the traits studied. The means of the 49 varieties for pod and kernel yields are shown in Table 1. Variety TAG 24 released in the year 1991 recorded the highest pod and kernel yields, while TKG 19A had the highest 100-seed weight of 49.4 g. The shelling outturn was the highest in GG 6 (71%), and so was the recovery of sound mature kernels (92%). The varieties were grouped into six classes based on the year of release *viz*., varieties released before 1960 (<1960), between 1961-1970, between 1971-1980, between 1981-1990, between 1991-2000 and varieties released after 2001 (>2001) (Table 2). The general trend over the years for pod and kernel yields, pod weight, seed weight, shelling outturn and recovery of SMK are depicted in Fig. 1. All the traits except shelling outturn exhibited a general increasing trend. In the case of shelling outturn, there was a slight declining trend over the decades as shelling is a complex trait that varies depending upon soil, climate and genetic factors. The pod and kernel yields showed a steady increasing trend starting from the early 1980s when the breeding emphasis was focused on selection from exotic germplasm, incorporation of potential germplasm into the locally adapted genotypes, and generation of variability through hybridisation followed by yield based selections. The release of improved varieties during this decade also led to added production of groundnut in the following decade. As the present study included varieties released for different agro-climatic zones of India, results from a multi-location evaluation trial in Spanish growing areas, instead of a single location trial, would have been more interesting and informative.

Table 2 Mean performance of 49 Spanish groundnut varieties grouped according to year of release

Year of release	Pod yield (kg/ha)		Kernel yield (kg/ha)	100-pod weight (g)	100-seed weight (g)	Shelling outturn (%)	Sound mature kernels (%)
	Mean	Highest					
Before 1960	995	1047 (TMV 2)	665	73.1	32.6	66.7	85.5
1961-1970	1042	1184 (SB XI)	683	74.5	33.3	64.4	83.2
1971-1980	966	1200 (Jyothi)	609	72.2	31.3	62.6	83.4
1981-1990	1254	1844 (RG 141)	800	81.5	35.0	63.9	86.0
1991-2000	1490	2335 (TAG 24)	985	85.8	37.6	66.0	87.3
After 2001	1702	1917 (GG 7)	1083	87.8	36.4	63.6	89.1

The best variety in terms of yield performance, released prior to 1960 was TMV 2 with a mean pod yield of 1047 kg/ha. The best variety released between 1961 and 1970 was found to be SB XI while for the next decade it was Jyothi. RG 141 and TAG 24 were the best varieties released during 1981-90 and 1991-2000, respectively. Only two varieties released after 2000 were used in the study and GG 7 was found to be the best. The percentage improvement in yield of the best variety released during each decade over TMV 2, released in 1940, was calculated. The pod yield superiority in SB XI, Jyothi and RG 141 was to the tune of 13%, 15% and 76%, respectively. The highest yielder TAG 24, released in 1991, recorded more than 100% improvement over TMV 2 with nearly 123% pod yield advantage. TAG 24, a compact and dwarf plant type has high harvest index due to its high partitioning ability (Badigannavar *et al.*, 2002) and water-use efficiency. Duncan *et al.* (1978) had also reported that in order to improve groundnut yield in future genotypes having higher partitioning efficiency should be developed. Out of two varieties released after 2000, GG 7 recorded pod yield advantage of 83% over TMV 2. Many high yielding varieties have been released in the recent years after the release of GG 7 and study of superiority in these would give a better picture of improvement made during the current decade.

Genetic gains were estimated between 1.3 to 3.2% per year under rainfed cultivation in India (Nigam *et al.*, 1994). Improved yield levels through concerted breeding efforts in groundnut have also been reported elsewhere. Duncan *et al.* (1978) reported significant improvement in runner cultivars in Florida since the start of the breeding programmes in 1928. They reported as much as 100% yield increase due to cultivar changes when comparing the first cultivar released to the latest release. Wynne and Gregory (1981) reported yield increases of 3, 12 and 19% when comparing an improved variety released during the 1950s, 1960s, and 1970s, respectively, to a land race (NC 4) grown in North Carolina. Mozingo *et al.* (1987) undertook a study to determine the genetic improvement in yield, market grade, and value of large-seeded Virginia groundnut cultivars released since the establishment of breeding programmes in the Virginia-North Carolina production area. The highest yielding cultivar developed during the 1950s, 1960s, and 1970s had an average yield increase of 3.4, 10.2, and 18.5%, respectively, over the standard, NC 4. They opined that the cultivars released during the 1980s could not surpass the cultivar with the highest yield developed during the 1970s because of the emphasis placed on pest resistance and quality acceptance during the 1970s.

Plotting pod yields of the 49 varieties vs. year released (Fig. 2) showed an upward trend. Linear ® = 0.483, P <0.01) regression calculated was highly significant with a 9.4 kg/ha yearly increase in pod yield. Plotting the kernel yield against year of release also gave highly significant regression ® = 0.453, P < 0.01) with an annual increase of 6.2 kg/ha. By plotting the pod yields of the best variety released for each decade of development (Fig. 3), the trend in improvement was greater with a 24.1 kg/ha yearly increase ® = 0.873, P < 0.05). This improvement should be more representative of the genetic improvement accomplished as each of the variety used in the analysis represents the variety with the highest yield potential for that decade. Comparing the best yielder for each decade with the land race NC 4, Mozingo *et al.* (1987) reported that the genetic improvement had accounted for yearly yield increase of 14.7 kg/ha in the Virginia-North Carolina groundnut production area. The genetic improvement achieved in the Spanish type groundnut cultivars in India thus appears more promising.

The genetic improvement achieved for pod and kernel yields must have come through active breeding efforts aimed at improving one or more of the yield components. From the trends depicted in Fig. 1 one can make out that the average HPW and HSW of varieties released in the mid-1980s recorded a steady jump compared to the previous decade. The shelling outturn remained almost constant during this period but showed a slight increase and declined subsequently. Manivel *et al.* (2000) attributed HSW to be one of the important factors that contributed to the yield improvement in Indian groundnut varieties and indicated that shelling percentage is a less stable yield component as it showed year-to-year variation. Apart from pod and seed weight the number of pods/plant as well as pod yield/plant could also be a major factor deciding the gain in yield potential of the varieties. Phenotypic selection practised by the breeders in the segregating generations place greater emphasis on the number of pods/plant with uniform maturity followed by the pod size and pod characteristics like shape, reticulation, constriction etc.

In order to examine the genetic improvement in yield related traits like pod number, pod weight, etc., the mean values of the varieties for these traits were plotted against the year of release. The pod yield per plant showed a very strong linear regression ® = 0.505, P < 0.01). The linear regression of number of pods/plant (Fig. 4) was significant ® = 0.367, P < 0.01) indicating the genetic gain that has occurred over the years from this trait has contributed towards enhanced pod yields. Incorporation of important germplasm like EC 94943, Ah 6279, EC 16659, Asiriya Mwitunde, Robut 33-1, NCAc 17090, etc., in the breeding programmes during 1970s and 1980s had contributed in development of varieties with high yield potential than the existing cultivars (Basu and Reddy, 1987). Breeding techniques like mutation has also paid rich dividends in groundnut in modifying the plant architecture like reducing the plant height, enhancing the number of pods. etc. Varieties, TAG 24 and TG 26, developed through mutagenesis followed by recombination breeding at the Bhabha Atomic Research Centre (BARC), Trombay, recorded the highest number of pods/plant, and TAG 24 eventually had the highest pod yield also among the varieties studied. Both TAG 24 and TG 26 are early maturing, semi-dwarf varieties with high pod growth rate, high harvest index and greater partitioning efficiency (Badigannavar *et al.*, 2002). A rapid expansion phenophase, a short podding phenophase, a long filling phenophase and a high partitioning of assimilates to pods were considered to be the physiological criteria responsible for higher yields by Mc Cloud *et al.* (1980). Varieties TAG 24 and TG 26, with high yield potential nearly satisfy these criteria and thus substantiate Mc Cloud *et al.* (1980) conclusions.

It is believed that varietal improvement in most peanut growing states in India was brought about through progressive improvement in pod size especially up to 1980s (Reddy, 1988). For example, among the Spanish varieties, the pod weight increased from 72 g in AK 12-24 (1940) to 75 g in SB XI (1965), 119 g in JL 24 (1978) and 120 g in TG 17 (1982) in Maharashtra; from 77 g in S 206 (1969) to 88 g in Dh 3-30 (1975) in Karnataka and from 76 g in TMV 2 (1940) to 91 g in TMV 7 (1967) and 92 g in TMV 9 (1970) in Tamil Nadu. In the present study, genetic improvement in pod and seed weight was also worked out through plotting the mean values vs. year of release. The HPW showed significant improvement ® = 0.3, P < 0.05) over the years (Fig. 5). However, the magnitude of annual gain was only marginal. The genetic gain in seed weight (Fig. 6) was also significant ® = 0.288, P < 0.05), but with only a marginal gain over the years. Limited availability of sufficient variability for pod and seed size among the Spanish germplasm collection could be one of the reasons in non-realisation of highly significant improvements for these traits through conventional breeding approaches, whereas Virginia germplasm holds more promise for pod

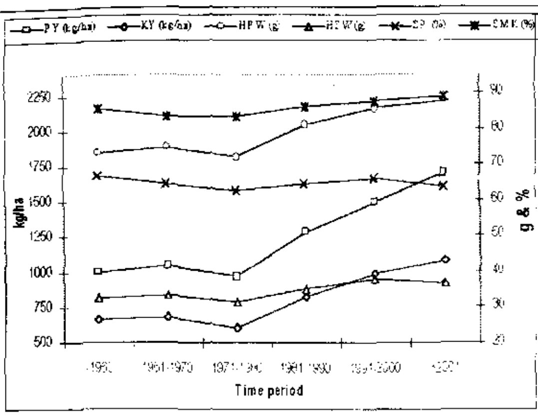

Figure 1. General trend over the years for different traits

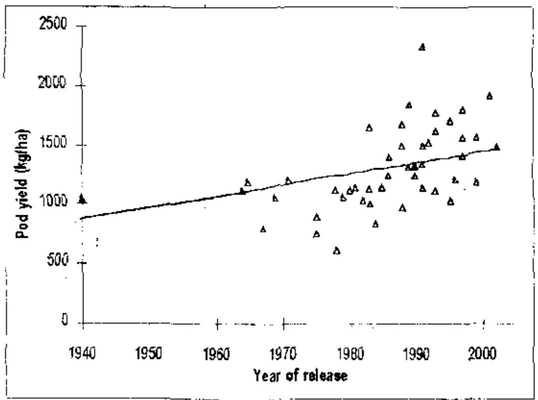

Figure 2. Linear regression of pod yield for 49 varieties vs. year released

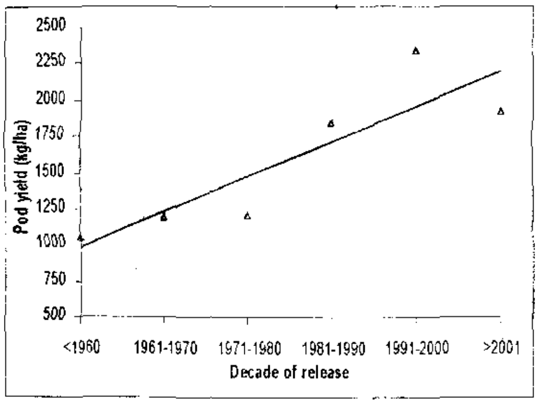

Figure 3. Linear regression of best variety pod yield for each decade vs. decade of release

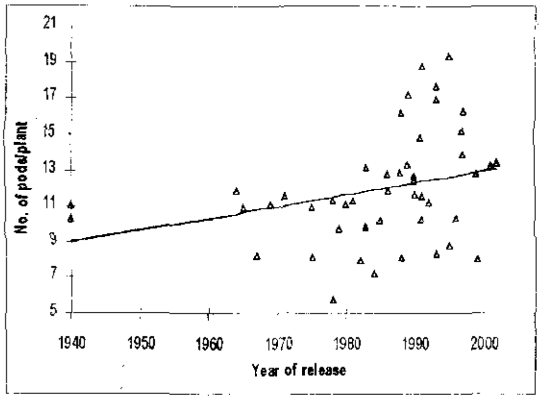

Figure 4. Linear regression of no. of pods/plant for 49 varieties vs. year released

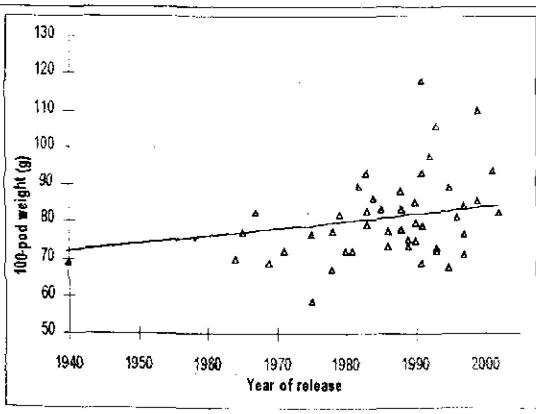

Figure 5. Linear regression of 100-pod weight for 49 varieties vs. year released

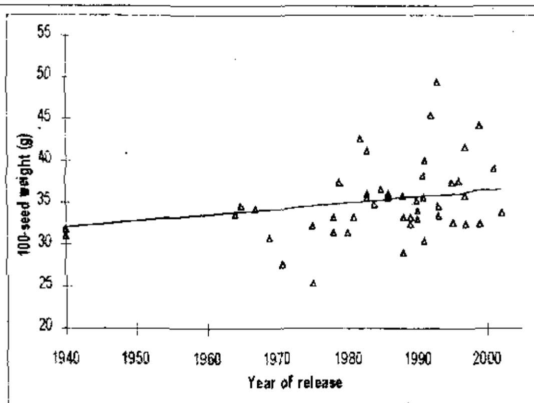

Figure 6. Linear regression of 100-seed weight for 49 varieties vs. year released

and seed size improvements. Moreover, the yield *per se* was the prime consideration by the breeders and not pod number or increased pod or seed size in isolation. Physical mutagenesis at the BARC has resulted in development of a number of mutant lines with enhanced pod and seed weight (Murthy *et al.*, 2004). Mutation and recombination breeding at the BARC succeeded in developing several large-seeded genotypes of which TG1, TKG 19A and Somnath (TGS 1) were released for cultivation in India (Kale *et al.*, 2000). In the present study, TKG 19A, and TG 22- another cross derivative developed at the BARC recorded high HSW (49.4 g and 45.4 g, respectively). Other mutant lines with large pod and seed are regularly being used in the groundnut improvement programmes aimed at developing large-seeded groundnut varieties. In the year 2004 a new confectionery and large-seeded groundnut variety, TPG 41, was released for commercial cultivation (Kale *et al.*, 2004).

The quality characters on which emphasis is laid in the varietal development in India are shelling percentage and oil content because they directly influence the oil yield per unit area. High shelling lines like Ah 7148, C 246, C 156, EC 24425 and EC 24444 were included as donor parents in the hybridization programmes launched under AICORPO groundnut centres (Reddy, 1988). In spite of enhanced emphasis on improving the shelling outturn and other quality attributes like SMK over the years, the improvement in these traits were not appreciable as evidenced in the present study. Though a slight improvement in shelling outturn was observed in the groundnut varieties released over the years (Basu and Rathnakumar, 2004), in the 49 Spanish varieties studied here the shelling outturn remained nearly constant over the years. The regression calculated was non-significant ® = 0.051, P = 0.73). In case of SMK percentage also the regression indicated non-significant ® = 0.217, P = 0.134) improvement. This may be due to applying high selection pressure on number of pods than the seed weight alone. Also, it can be hypothesized that as the Spanish types, in general, are determinate in growth habit with nearly uniform maturity, significant improvement in SMK could not be realized through conventional breeding approaches.

A limitation often groundnut breeders put forth to increase groundnut productivity is the availability of relatively low genetic variability in the germplasm commonly used in the breeding programmes. However, very little of the large genetic variability in the germplasm accessions has been utilized in crop improvement programmes. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) holds in trust in excess of 15000 accessions of cultivated groundnut but very few have been used in the improvement programme (Upadhyaya *et al.*, 2003) suggesting that most groundnut cultivars have a very narrow genetic base. Though there are examples where plant breeders have effectively exploited the exotic germplasm for incorporation of disease resistance or other single gene controlled traits (Stalker, 1980), use of exotic germplasm in improvement of quantitative traits is rare. Halward and Wynne (1991) opined that groundnut improvement programmes aimed at rapid cultivar development rely mostly on established cultivars and elite breeding lines in developing breeding materials, rather than using exotic germplasm. With the availability of information on core collection or mini-core collection that captures most of the variability in the germplasm (Upadhyaya *et al.*, 2002; Upadhyaya, 2003) groundnut breeders should be able to incorporate more germplasm accessions in breeding programmes in future.

To conclude, results from the study show that progress has been made in genetic improvement of the Spanish type groundnut since organized breeding programmes began in India. As Spanish type varieties contribute more than 50% of the total groundnut production of the country the genetic improvement gained in yield potential is really a commendable achievement for the groundnut breeders. The alterations in plant architecture with reduced height, erect growth habit, more number of pods, etc., are the main landmarks in the Spanish groundnut improvement. Progress in improvement of other characteristics like quality, shelling outturn, pest resistance, drought tolerance, etc., should be more focused in the breeding programmes in future in order to further consolidate the yield gains in groundnut. Utilization of large genetic variability contained in the germplasm accessions has to be given priority. The farmers' preference for erect, spreading or semi-spreading habit type would also decide the magnitude of emphasis to be placed in the improvement of Spanish type groundnut.

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Genetic variation and trait relationships in summer groundnut, *Arachis hypogaea* L.

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Abstract

Fifty elite genotypes of bunch groundnut, *Arachis hypogaea* (L.) were evaluated in summer season to know the extent of genetic variability, nature and magnitude of association among the yield traits and their direct and indirect effects on pod yield. High magnitude of GCV and PCV for pods/plant, kernel yield/plant and pod yield/plant indicated large extent of genetic variability for these traits in the material. High heritability was accompanied by high genetic advance for plant height and 100 pod weight, whereas, moderate heritability was associated with high genetic advance and high GCV for pods per plant and kernel yield/plant, indicating involvement of additive gene action for these traits. Pod yield/plant expressed high genetic advance with low heritability, however, its high magnitude of GCV suggested the scope of pod yield improvement. Pod yield/plant was associated strongly and positively with kernel yield/plant, pods/plant, shelling outturn and oil content but its correlation was significantly negative with 100 pod weight, days to 50% flowering and days to maturity. Pods/plant manifested maximum direct effects towards pod yield/plant followed by 100 pod weight and 100 kernel weights. Pods/plant and kernel yield/plant also contributed major share to pod yield/plant indirectly through other traits. Thus, pods/plant and kernel yield/plant would be the important component traits of pod yield and should be considered as selection criteria for enhancing yield in summer groundnut.

Key words: *Arachis hypogaea*, variability, correlation, path effects

Introduction

The groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops, commercially popular due to its superior quality of edible oil and protein. It has a wide range of adaptability in varying agro-climatic conditions and soils. Among the groundnut growing states, Gujarat ranks first in production and second in area in the country. In Gujarat, summer groundnut (bunch type) is usually grown under irrigated conditions and has much higher productivity than *kharif* groundnut. As a result, it gives large profits despite the high cost of production than the *kharif* season.

Since the economic part of groundnut known as pod is developed under the soil, prediction of its performance based on aerial morphological characters is almost difficult (Weiss, 2000). As it is a highly self-pollinated crop, the variability observed within the habit groups reported to be very low. In fact, genetic variability is of greater interest to the plant breeder as it plays a vital role in framing a successful breeding programme. Further, correlation and path analysis is helpful to determine the magnitude of association among the variables and relative contribution of them on yield. Such information in groundnut especially under summer condition is limited. Therefore, present study was undertaken to know the extent of variability, nature and magnitude of relationships among yield traits and their direct and indirect effects towards pod yield in summer groundnut.

Materials and methods

The experimental material comprising of 50 genotypes of bunch groundnut was laid out in a randomized block design with three replications at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh under irrigated condition during summer, 2005. Each entry was accommodated in a single row of 3m length with a spacing of 30 cm x 10 cm. Guard rows on both side of every nine lines and also surrounding the experiment were provided to avoid border effects.

All management practices in vogue for summer cultivation were followed for reaping good crop. The observations were recorded on five randomly selected plants in each entry for 13 agronomic traits and the average values were used for statistical analysis. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were estimated. Heritability in broad sense and genetic advance as percentage of mean were calculated. Genotypic correlation coefficients and path coefficients were estimated.

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Results and discussion

There was a considerable role of environmental factors in expression of all the traits as depicted by higher values of PCV than corresponding GCV (Table 1). It was noted that the magnitude of GCV and PCV was high for pods/plant, kernel yield/plant and pod yield/plant, moderate for plant height, 100 pod weight, 100 kernel weight and branches/ plant and low for days to first flower, days to 50% flowering, days to maturity, shelling out turn, SMK% and oil content. Our findings are in close agreement with the results reported by Golakia *et al.* (2005). On the other hand, lower magnitude of variability for shelling out turn and oil content as observed in the present study suggested that large number of germplasm lines needs to be screened for identifying genotypes with high shelling and oil (Bhagat *et al.*, 1986).

The estimate of heritability in broad sense varied from 18.30% for SMK% to 68.60% for shelling out turn. Similarly, genetic advance as percentage of mean observed to be minimum for days to first flower to the maximum for pods/plant. However, it is evident from the data that magnitude of heritability was high for shelling out turn (68.80%), plant height (66.30%), 100 pod weight (65.40%) and days to maturity (64.40%). Likewise, high magnitude of genetic advance was observed for pods/plant (44.33%), kernel yield/plant (33.66%), plant height (30.33%), pod yield/plant (26.13%) and 100 pod weight (24.74%).

High heritability coupled with high genetic advance and moderate GCV was noted for plant height and 100 pod weight, indicating involvement of additive gene action and scope of improvement of these characters through selection. Economically important characters like pod and kernel yield/plant showing low to moderate heritability along with high genetic advance and high GCV suggested that these characters should largely be under the control of additive gene action and lower estimates of heritability may be due to larger influence of environmental factors. In many instances including pod and kernel yield/plant, high estimates of heritability were not associated with the high values of genetic advance and *vice-versa*. This might be due to lower or higher values of phenotypic standard deviation which determines the value of genetic advance. In such a situation, variability in base populations would be more useful than the magnitude of heritability alone for selecting better genotype (Johnson *et al.*, 1955). Similar observations have also been reported by Venkataravana *et al.* (2004).

The genotypic correlation coefficients (Table 2) obtained among 13 characters revealed most striking association of pod yield/plant with kernel yield/plant and pods/plant. These findings are in accordance with the results obtained by Golakia *et al.* (2005), Venkateswarlu *et al.* (2007) and Parmeshwarappa *et al.* (2008). Kernel yield/plant and pods/plant were observed to be associated significantly and positively between themselves as well as with shelling out turn. There was a significant positive association between shelling out turn and pod yield/plant. However, 100 pod weight showed significant negative correlation with pod yield/plant, shelling outturn and 100 kernel weight. This indicated that selection for smaller pod size would increase pod yield, shelling outturn and kernel size. Many of the earlier studies indicated strong association between shelling outturn and pod yield (Hoque *et al.*, 1993 and Dashora and Nagda, 2002). Pod yield exhibited moderate positive association with SMK% which was in agreement with the results obtained by Parmeshwarappa *et al.* (2008).

Pod features like filled pods and better kernel recovery are desirable to attract both consumers and producers. A positive association of shelling out turn with SMK% and 100 kernel weight indicated that an increase in shelling out turn would be responsible for higher SMK% and 100 kernel weight. Days to 50% flowering and days to maturity had significant and negative association with pod and kernel yield/plant, and pods/plant. This indicates that selection for higher yielding early genotypes with increasing pods/plant is possible. The genotypes having uniform kernels normally fetch premium value. Significant positive relationship between SMK% and 100 kernel weight indicated that it may be possible to isolate large seeded genotypes with higher proportion of uniform kernels. Parmeshwarappa *et al.* (2008) have reported similar observations.

High oil content in groundnut is economically desirable characteristic. Its significant and positive association with pod and kernel yield/plant and days to maturity and significant negative association with days to 50% flowering revealed that there is a need to develop genotypes which can flower early and mature as late as possible so that maximum duration prevail for oil formation leading to higher pod yield.

Pods/plant had the highest direct contribution (2.27) towards pod yield followed by kernel yield/plant (-0.89), 100 kernel weight (0.66) and 100 pod weight (0.63) (Table 3). It was further noted that though the direct effects of kernel yield/plant was negative, its positive indirect influence through pods/plant (1.99) supported positive association with pod yield. On the contrary, 100 pod weight and 100 kernel weight also expressed high positive direct effects, but their negative indirect contributions through pods/plant (-1.67 and -0.77, respectively) should be responsible for significant negative and non-significant correlations with pod yield, respectively.

Direct contribution of days to 50% flowering and days to maturity towards pod yield/plant appeared to be low, but at the same time their negative indirect influence (desirable) through pods/plant was considerable. Pods/plant observed to be major indirect contributor towards pod yield through most of the characters studied. Second most important character contributing indirectly was kernel yield/plant. A situation like this where few characters shared a major responsibility in enhancing the yield potential in groundnut was reported by Deshmukh *et al.* (1986) and Parmeshwarappa *et al.* (2008). Present study, thus, indicated that prime emphasis should be given to pods/plant and kernel yield/plant in summer groundnut breeding programme.

Table 1 Phenotypic (PCV) and genotypic (GCV) coefficients of variation, heritability (h^2) and genetic advance (GA) for various characters in summer groundnut

Character	PCV (%)	GCV (%)	h^2 (%)	GA as % mean
Days to first flower	5.39	2.34	18.90	2.00
Days to 50% flowering	9.18	6.36	47.90	9.00
Days to maturity	3.02	2.42	64.40	4.02
Plant height (cm)	22.33	18.18	66.30	30.53
Branches/plant	15.85	11.65	54.10	17.70
Pods/plant	39.20	29.05	54.90	44.33
100 pod weight (g)	19.13	15.47	65.40	24.74
100 kernel weight (g)	25.97	13.67	27.70	12.61
Shelling outturn (%)	9.31	7.71	68.60	13.16
SMK %	8.9	3.81	18.30	3.36
Oil (%)	4.54	2.60	32.80	3.07
Kernel yield/plant (g)	36.01	24.24	45.30	33.66
Pod yield/plant (g)	34.61	20.92	36.80	26.13

Table 2 Genotypic correlation coefficients among various characters of summer groundnut

Character	Days to 50% flowering	Days to maturity	Plant *height* (cm)	Branches/ plant	*Pods/plant*	100 pod weight (g)	100 kernel weight (g)	Shelling *outturn* (%)	SMK (%)	Oil (%)	Kernel *yield/plant* (g)	Pod *yield/* plant (g)
Days to first flower	0.99**	0.45**	-0.05	0.65**	-0.31*	0.25	0.16	-0.30*	-0.19	-0.24	-0.47**	-0.36*
Days to 50% flowering		0.51**	-0.29*	0.49**	-0.44**	0.10	-0.14	-0.42**	0.03	-0.42**	-0.64**	-0.54**
Days to maturity			-0.21	0.44**	-0.37**	0.20	0.08	-0.26	-0.05	0.29*	-0.42**	-0.41**
Plant height *(cm)*				0.14	0.11	*0.15*	*0.34**	*0.17*	*0.26*	*0.35**	*0.27*	*0.25*
Braches/plant					-0.43**	0.52**	0.47**	-0.34*	-0.05	0.39**	-0.39**	-0.33*
Pods/plant						-0.74**	-0.34*	0.55**	0.11	0.25	0.88**	0.90**
100 pod weight (g)							-0.79**	-0.37*	0.23	0.24	-0.40**	-0.40**
100 kernel weight (g)								0.16	0.64**	0.27	0.12	0.01
Shelling outturn (%)									0.65**	-0.11	0.73**	0.51**
SMK %										0.07	0.46**	0.34*
Oil (%)											0.28*	0.40**
Kernel yield/ plant (g)												0.96**

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

Table 3 Direct (diagonal) and indirect (non-diagonal) effects of various characters on pod yield in summer groundnut

Character	Days to first flower	Days to 50% flowering	Days to maturity	Plant height (cm)	Branches/ plant	Pods/ plant	100 pod weight (g)	100 kernel weight (g)	Shelling outturn (%)	SMK (%)	Oil (%)	Kernel yield/ plant (g)	Correlation with pod yield/ plant (g)
Days to first flower	0.01	0.11	0.01	0.00	-0.26	-0.72	-0.15	-0.15	0.00	0.02	0.02	0.42	-0.36*
Days to 50% flowering	0.01	0.11	0.01	-0.02	-0.20	-1.00	0.06	0.00	-0.09	0.00	-0.03	0.57	-0.54**
Days to maturity	0.01	0.05	0.02	-0.02	-0.18	-0.83	0.13	0.00	0.05	-0.01	-0.02	0.37	-0.41**
Plant height (cm)	*0.00*	-0.03	-0.01	*0.07*	*-0.05*	*0.24*	*0.10*	*0.23*	*0.00*	*-0.03*	*-0.02*	*-0.24*	0.25
Branches/plant	*0.01*	0.05	0.01	0.01	-0.40	-0.97	0.33	0.31	0.00	0.01	-0.03	0.35	-0.33*
Pods/plant	0.00	-0.05	-0.01	0.01	-0.17	2.27	-0.46	-0.22	0.00	-0.01	0.02	-0.78	0.90**
100 pod weight (g)	0.00	0.01	0.01	0.01	-0.21	-1.67	0.63	0.52	0.00	-0.02	-0.02	0.35	-0.40**
100 kernel weight (g)	0.00	-0.02	0.00	-0.02	-0.20	-0.77	0.50	0.66	0.00	-0.07	-0.02	-0.11	0.01
Shelling outturn (%)	0.00	-0.05	-0.01	0.01	0.14	1.24	-0.23	0.11	0.01	0.07	0.01	0.65	0.51**
SMK %	*0.00*	*0.00*	0.00	0.02	0.02	0.26	0.14	0.42	0.01	-0.11	-0.01	-0.41	0.34*
Oil (%)	0.00	-0.04	0.01	0.02	-0.16	0.56	0.15	0.18	0.00	-0.01	-0.07	-0.25	0.40**
Kernel yield/ plant (g)	-0.01	-0.07	-0.01	0.02	0.16	1.99	-0.25	0.07	0.01	-0.05	0.02	-0.89	0.96**

*,** significant at 5% and 1% level, respectively; Residual effect = 0.03

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Integrated nitrogen management in groundnut, *Arachis hypogaea* L.-wheat, *Triticum aestivum* crop sequence under medium black calcareous soil of south Saurashtra region of Gujarat

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Abstract

A field experiment was conducted during 2000-01 to 2006-07 on medium black calcareous clay soil at Junagadh to evaluate the effect of integrated nitrogen management in groundnut (*Arachis hypogaea*) var. GG-20 - wheat (*Triticum aestivum*) var. GW-496 crop sequence. The study revealed that significantly higher pod yield (2000 kg/ha), nutrient uptake of NPK by groundnut pod, available N and K in soil after harvest of groundnut and available K after harvest of wheat were observed under 100% recommended dose of nitrogen of each crop applied through FYM. Significantly higher grain (4034 kg/ha) and straw yield (4680 kg/ha) of wheat were registered when both the crops received fertilizers as per soil test basis. Significantly higher uptake of NPK by groundnut haulm, wheat grain and straw, higher gross (Rs. 85396/ha) and net returns (Rs. 58168/ha) as well as B:C ratio (3.14) were realized when each crop was fertilized as per soil test basis.

Key words: Groundnut, wheat, INM, RDN, FYM, crop sequence

Introduction

Continuous use of chemical fertilizers alone is reported to deteriorate soil health and reduce crop productivity. The crops grown in a sequence may require differential application of fertilizer nutrients than those grown as individuals (Mishra and Vyas, 1992). Groundnut-wheat is the most popular cropping system in Saurashtra region of Gujarat. However, the yield of groundnut is very low and inadequate and imbalanced use of fertilizers is one of the several reasons. Information on nutrient requirement for this cropping system particularly when the nutrients are supplied partially through organic and inorganic sources is limited. Sustainability of higher yields could be achieved through integrated nutrient management (Singh *et al.*, 1990). Therefore, the present experiment on integrated nitrogen management in groundnut-wheat crop sequence was conducted in the south Saurashtra region of Gujarat with main objectives *viz.*, to study the effect of organic sources of nitrogen on yield, uptake and nutrient status of soil in groundnut-wheat crop sequence and to find out the economically viable dose of organic and inorganic source of nitrogen for groundnut-wheat crop sequence.

Materials and methods

A field experiment was conducted with groundnut in the rainy season followed by wheat in the winter season from 2000-01 to 2006-07 at, Junagadh Agricultural University, Junagadh (Gujarat). The soil was medium black calcareous clayey in texture, having pH 7.9, organic carbon (O.C.) 0.63%, rich in available N 210.8 kg/ha, high in available P 48.4 kg/ha, low in available K 242.0 kg/ha, and medium in available S 10.2 mg/kg. The ten treatments comprising of combinations of manures and chemical fertilizers in different proportions were tested in randomized block design with 4 replications. Treatments were: T_1-FYM (100% RDN), T_2-FYM (75% RDN) + castor cake (25% RDN), T_3-FYM (50% RDN) + castor cake (50% RDN), T_4-FYM (25% RDN) + castor cake (75% RDN), T_5-Castor cake (100% RDN), T_6-Organic fertilizer (25% RDN, of which 50% N each from FYM and castor cake) + inorganic fertilizers (75% RDN), T_7-Organic fertilizer (50% RDN of which 50% N each from FYM and castor cake) + inorganic fertilizers (50% N), T_8-Organic fertilizer (75% RDN, of which 50% N each from FYM and castor cake) + inorganic fertilizers (25% N), T_9-Inorganic fertilizers (100% as per soil test) and T_{10}-Inorganic fertilizers (100% as per recommendation). In treatments 1 to 8, N was applied as per recommendation instead of soil test and no P and K doses were applied. The groundnut cv. GG-20 and wheat cv. GW-496 were sown with recommended agronomic practices, except nutrient application. All the organic manures and chemical fertilizers were incorporated in individual plots in the previously opened furrows at 60cm for groundnut and 22.5cm for wheat crop as per treatments before sowing the crop. Soil samples collected from each plot from 0-15cm depth in the beginning of experiment and after harvest of crop every season were analyzed for O.C., available N, P, K and S. Observations on yields were recorded for each treatment and economics was worked out using current market prices of produce and inputs used.

Results and discussion

Groundnut

Seven years pooled results presented in table 1 revealed that highest groundnut pod yield (2000 kg/ha) was registered in 100% recommended dose of N (100% RDN) applied through FYM to both the crops and was comparable with 75% RDN applied through FYM + 25% RDN applied through castor cake and significantly higher than rest of the treatments. Improvement in pod yield due to application of RDN through FYM was to the tune of 30.2% over 100% N applied through inorganic fertilizer. This particular benefit may be attributed to the effect of FYM on physical properties, moisture conservation and augmenting the soil availability of K. Similar benefit was also observed by Kathmale *et al.* (2000) and Singh (1999). Significantly higher haulm yield (3607 kg/ha) was produced when groundnut was fertilized with inorganic fertilizers as per soil test value. However, this treatment was at par with application of 100% RDN through FYM and 75% RDN through FYM and 25% RDN through castor cake. Similar results were also reported by Dudhatra *et al.* (2002) and Malavia *et al.* (2000).

Table 1 Effect of different treatments on yield and economics of groundnut-wheat crop sequence (mean of seven years)

Treatment	Yield (kg/ha)				Economics (Rs./ha)		B:C ratio
	Groundnut		Wheat		Income	Returns	
	Pod	Haulm	Grain	Straw			
T_1-100% FYM	2000	3525	3605	4430	86710	56731	2.89
T_2-75% FYM +25% CC	1835	3559	3465	4252	81117	50923	2.69
T_3- 50% FYM +50% CC	1711	3162	3401	4106	77484	47075	2.55
T_4- 25% FYM +75% CC	1726	3094	3179	3889	75579	44955	2.47
T_5- 100% CC	1656	3063	3500	3939	76855	46017	2.49
T_6- 12.5% FYM +12.5% CC+75% inorganic say urea	1685	3188	3569	4109	77407	50394	2.86
T_7-25% FYM +25% CC+50% inorganic	1683	3193	3678	4123	79418	51071	2.80
T_8- 37.5 FYM +37.5% CC+25% inorganic	1679	2989	3643	3955	78521	49263	2.68
T_9- 100% inorganic (soil test bases)	1757	3607	4034	4680	85396	58168	3.14
T_{10}- 100% inorganic	1536	3028	3571	4291	74901	47792	2.57
CD (P=0.05)	229	205	295	222			

Wheat

In succeeding wheat, grain and straw yields differed significantly with treatments. The highest grain (4034 kg/ha) and straw (4680 kg/ha) yields were obtained with application of 100% N as inorganic fertilizers as per soil test value to both the crops, which was 13 and 9% higher as compared to crop fertilized as per recommended dose of fertilizers, respectively. Kathmale *et al.* (2000) and Golakiya *et al.* (2000) also reported similar trends. Upadhyay *et al.* (1997) noted that wheat was not influenced by the residual effect of fertilizers applied to groundnut.

Economics of cropping system

The economics of various treatments presented in table 1 indicated that application of inorganic fertilizers as per soil test basis resulted in highest gross (Rs. 85396/ha) and net returns (Rs. 58168/ha) with 3.14 benefit : cost ratio.

Nutrient uptake

Groundnut

The uptake of NPK by pod and haulm varied phenomenally among the treatments (Table 2). The higher uptake of N (56.9 kg/ha), P (5.2 kg/ha) and K (10.2 kg/ha) by pods was associated with 100% RDN applied through FYM to each crop was on par with FYM (75% RDN) + castor cake (25% RDN), FYM (25% RDN) + castor cake (75% RDN) and inorganic fertilizers (100% on soil test basis). Application of fertilizers on soil test basis to both the crops registered highest N (63.5 kg/ha), P (5.4 kg/ha) and K (15.6 kg/ha) uptake by haulm which was comparable with FYM (100% RDN) and FYM (75% RDN) + castor cake (25% RDN).

Wheat

NPK uptake by wheat grain and straw was significantly affected by various treatments (Table 2). Significantly highest N uptake of 75.4 and 31.1 kg/ha by grain and straw, respectively were recorded when both the crops were fertilized on soil test basis. Same treatment also registered higher P uptake (10.3 kg/ha) and (2.1 kg/ha) by grain and straw and was statistically at par with rest of the treatments except FYM (25% RDN) + castor cake (75% RDN) and organic fertilizer (25% RDN of which 50% N each from FYM and castor cake) + inorganic fertilizers (75% RDN) in case of P uptake by grain and with castor cake (100% RDN), organic fertilizer (50% RDN of which 50% N each from FYM and castor cake) + inorganic fertilizers (50% N) and inorganic fertilizers (100% as per recommendation) in case of P uptake by straw. Maximum K uptake by grain (13.3 kg/ha) and straw (41.8 kg/ha) was found under same treatment which remained at par with FYM (100% RDN), organic fertilizer (50% RDN of which 50% N each from FYM and castor cake) + inorganic fertilizers (50% N) and organic fertilizer (75% RDN, of which 50% N each from FYM and castor cake) + inorganic fertilizers (25% N) for K uptake by grain and with FYM (100% RDN), FYM (75% RDN) + castor cake (25% RDN) and FYM (50%RDN) + castor cake (50% RDN) for K uptake by straw.

Post-harvest soil fertility after groundnut and whe_

Available NPK, O.C. and sulphur from soil were determined after completion of each crop. Mean data of seven years given in table 3 indicated that at the end of the experiment, different treatments had nonsignificant influence on nutrient status after harvest of each crop except available K after groundnut and wheat and N after groundnut wherein maximum available K and N were observed when 100% RDN to each crop was applied through FYM.

Table 2 Effect of different treatments on uptake (kg/ha) of N, P and K by groundnut-wheat sequence (seven years pooled)

Treatment (Recommended dose of nitrogen)	Nutrient uptake (kg/ha)											
	Groundnut						Wheat					
	Pod			Haulm			Grain			Straw		
	N	P	K	N	P	K	N	P	K	N	P	K
T_1-100% FYM	56.9	5.2	10.2	56.8	5.3	14.6	61.9	10.2	12.5	25.3	1.8	41.1
T_2-75% FYM +25% CC	54.4	5.0	9.7	57.4	5.0	14.9	61.9	9.5	12.0	23.1	1.6	41.1
T_3- 50% FYM +50% CC	46.5	4.6	9.2	56.6	4.9	13.9	61.3	9.2	11.6	25.8	1.5	38.2
T_4- 25% FYM +75% CC	49.3	5.0	9.5	56.5	4.8	13.5	59.5	8.5	11.1	22.4	1.5	36.8
T_5- 100% CC	45.7	4.5	8.5	53.4	4.8	12.9	64.1	9.4	11.8	24.2	1.9	36.1
T_6- 12.5% FYM +12.5% CC+75% inorganic say urea	47.7	4.6	8.7	56.0	4.8	13.5	66.4	8.7	11.4	24.4	1.7	34.3
T_7-25% FYM +25% CC+50% inorganic	45.5	4.6	8.6	55.4	5.1	13.8	67.6	9.6	12.2	26.0	2.0	37.9
T_8- 37.5 FYM +37.5% CC+25% inorganic	46.6	4.6	9.0	552	4.8	13.6	63.5	9.5	12.3	25.1	1.7	37.2
T_9- 100% inorganic (soil test bases)	52.1	4.7	9.3	63.5	5.4	15.6	75.4	10.3	13.3	31.1	2.1	41.8
T_{10}- 100% inorganic	44.3	4.1	8.3	52.0	5.1	14.0	67.5	9.7	12.2	28.1	1.9	35.6
CD (P=0.05)	8.4	0.6	1.2	6.1	0.4	1.3	7.3	1.1	1.1	3.5	0.3	3.7

Table 3 Effect of different treatments on soil nutrient status after harvest of groundnut and wheat (mean of seven years)

Treatment	O.C. (%)	Available nutrients after groundnut (kg/ha)			S (mg/kg)	O.C. (%)	Available nutrients after wheat (kg/ha)			S (mg/kg)
		N	P_2O_5	K_2O			N	P_2O_5	K_2O	
T_1	0.78	242.6	66.0	212.6	10.9	0.74	230.2	67.7	190.9	11.0
T_2	0.77	238.9	67.2	209.0	11.3	0.74	228.3	67.5	184.6	11.6
T_3	0.75	241.9	67.1	202.4	11.7	0.71	224.1	67.1	182.4	11.9
T_4	0.77	238.5	67.7	202.0	11.3	0.74	228.0	69.1	180.4	11.8
T_5	0.74	235.1	67.1	199.6	11.2	0.70	223.1	68.4	176.3	11.8
T_6	0.74	236.4	67.1	200.8	11.7	0.74	2242	67.0	168.9	11.4
T_7	0.75	233.8	67.1	196.3	11.7	0.72	224.1	68.4	172.7	12.1
T_8	0.77	231.1	66.8	193.8	11.8	0.79	223.6	68.0	175.7	11.9
T_9	0.74	231.6	69.2	191.7	11.6	0.73	222.9	68.9	170.2	12.2
T_{10}	0.76	232.3	67.5	182.2	11.8	0.72	225.5	68.1	164.0	12.1
CD (P=0.05)	NS	7.68	NS	7.84	NS	NS	NS	NS	5.50	NS

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Yield assessment of promising bunch groundnut, *Arachis hypogaea* L genotypes with fresh seed dormancy

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Abstract

The studies were conducted in summer season with 15 promising groundnut, *Arachis hypogaea* L. genotypes on clay soil at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh for yield assessment of promising bunch groundnut genotypes with fresh seed dormancy. Genotypes K-1375, BHG-9802 and TG-50 were significantly superior in pod yield along with 25, 15 and 4% germination after 15 days of harvest, respectively. The genotypes JALW-26, SG-99 and ICR-24 possessed less than 30% germination and were better than other genotypes. Genotypes AG-2238, JB-1077, JB-1078, Dh-101, JALW-09, ICR-48 and ICGV-92121 were least dormant against the genotypes K-1375, BHG-9802, TG-50, JALW-26, SG-99, and ICR-24 which were the most dormant and high yielding.

Key words: Groundnut, genotypes, intensity, dormancy, yields

Introduction

Groundnut is grown on 26 m. ha worldwide. India is the second largest groundnut producing nation in the world, harvesting 7.0 m. metric tonnes in 2006-07(Verma *et al.*, 2009). In Gujarat, the Saurashtra region which is one of the most drought prone areas, contributes 85 and 81% of the area and production, respectively to groundnut. Groundnut genotypes lack fresh seed dormancy. Therefore, testing for fresh seed dormancy in groundnut is an important activity in environments, where rains may occur at maturity time. Our objectives in this study were (I) to assess yield performance of promising genotypes originating from Spanish x Spanish crosses, (ii) to estimate the degree of dormancy of advanced genotypes and (iii) to estimate the duration of their fresh seed dormancy and rank them using the scale of Landfort *et al.* (1965).

Materials and methods

During 2001-04 period, 208 Spanish bunch advanced breeding lines were screened for presence of fresh seed dormancy (FSD). Entries having less than 30% germination were selected for evaluating FSD. Promising genotypes were maintained in a nursery and repeated tested for dormancy during summer and *kharif* seasons. Out of these, 15 promising genotypes were selected. These 15 genotypes were compared with released varieties used as check. The released varieties GG-2, TG-26 and GG-7 are commonly cultivated in Gujarat state and are early maturing (95 days) but without fresh seed dormancy and most susceptible to *in situ* germination. The experiment was conducted in *kharif* at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh during year 2005-06 to 2008-09. The experimental design was a randomized complete block with three replications. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction. The soil has an organic carbon content of 0.54 % and was medium in available nitrogen, potash and sulphur, low in phosphorus. The entire dose of fertilizers, 12.5 kg N/ha and 25 kg P_2O_5/ha was applied basal as per recommendations. Normal cultural practices were followed during the growing season. At harvest, a sample of mature pods was randomly collected from each entry for the fresh seed dormancy test. The pods were shelled and enough caution was taken to prevent any damage of the seed components (testa, cotyledons and embryo). Since apical seeds are known to be less dormant than basal seeds (Ketring and Morgan, 1970). All the tests in this study were performed using apical seeds.

Concurrently to the field test, a test was performed in petri-dishes in laboratory using incubator at 35/27°C. Hundred seeds randomly selected were sown in a petri-dish using filter paper moistened with distilled water and replicated four times. The filter paper was maintained moist by adding distilled water every day and the experimentation lasted 7 days. Seed dormancy is characterized by its intensity and duration. These parameters were estimated as per Kumar *et al.* (1991). The duration of dormancy was measured by the number of days taken to attain 30% of germinated seeds. Duration of dormancy was calculated by the following formula: Degree of dormancy = No. of days taken to less than 30% of germination. The scale devised by Landfort *et al.* (1965) was used to rate the degree of dormancy. It was performed on data collected from the investigation.

Results and discussion

The highest pod yield was recorded by K-1375 followed by BHG-9802, JALW-26, TG-50, SG-99, ICR-48, ICR-24, ICGV-92121 and GG-2, while significantly highest haulm yield was recorded in BHG-9802 genotype. However, it was at par with Dh-101, JALW-26, SG-99 and ICGV-92121 genotypes (Table 1). Significantly highest biological yield was recorded by BHG-9802(4666 kg/ha), which was comparable with JALW-26, TG-50, K-1375 and ICGV-92121. Likewise, highest HI was recorded in TG-26 followed by JALW-26, TG-51, TG-50, K-1375, ICR-48 and ICR-24. The genotype, JALW-26 recorded the highest shelling per cent which was statistically at par with the K-1375, ICR-48, ICR-24, ICGV-92121, GG-2 and GG-7.

The lowest percentages of germinated seeds were observed with genotypes JALW-26, TG-51 and TG-50 (Table 2). The genotypes BHG-9802, JALW-26, TG-51, TG-50, SG-99, K-1375, ICR-48 and ICR-24 have shown less than 30% of germinated seeds at 7 and 15 days after harvest.

The genotypes JALW-26, TG-51 and TG-50 showed the highest intensity of dormancy at 7 and 15 days after harvest. While the non-dormant genotypes *viz.*, Dh-101, JALW-09 and ICGV-92121 exhibited the lowest intensity of dormancy.

Genotypes BHG-9802, JALW-26, TG-51, TG-50, SG-99 and ICR-24 were persistently more dormant genotypes (Table 1). Their duration of dormancy was more than 15 DAH. These results are consistent with the findings of many authors Pandya and Patel (1986) and Wadia *et al.* (1987). Actually, more the intensity of dormancy, the longer was the dormancy duration meaning that these genotypes showed strong and long duration seed dormancy. As the intensity of dormancy, the duration of dormancy for a given entry varied more or less over seasons due to non-genetic factors. Earlier, Kumar *et al.* (1991) reported that seed dormancy is influenced by environmental conditions.

When the scale of Landfort *et al.* (1965) was used, AG-2238, JB-1078, JB-1077, Dh-101, JALW-09, ICR-48, ICGV-92121 and check varieties (GG-2, GG-7 and TG-26) formed the group in which entries were non-dormant. The remaining genotypes were dormant.

Table 1 Effect of different genotypes on shelling, harvest index, yield, germination and intensity of dormancy of groundnut (Pooled data of 2005, 2007 and 2008 years)

Genotype	Pod yield (kg/ha)	Fodder yield (kg/ha)	Total biomass (kg/ha)	Harvest index (%)	Shelling (%)	Germination (%)		Intensity of dormancy (%)	
						At 7 DAH	At 15 DAH	At 7 DAH	At 15 DAH
AG-2238	921	2472	3392	27.5	64.5	38	55	62	45
JB-1077	934	2350	3284	28.4	68.3	54	64	46	36
JB-1078	1085	2456	3542	31.8	65.9	62	85	38	15
Dh-101	1126	2613	2740	29.1	67.7	79	89	21	11
BHG-9802	1470	3196	4666	30.1	62.9	11	15	89	85
JALW-26	1301	2836	4137	31.9	70.8	4	7	96	93
TG-51	1054	2201	3256	32.4	65.3	1	7	99	93
JALW-09	771	1838	2609	30.5	62.7	84	95	16	5
JALW-27	1121	2437	3559	31.5	65.5	3	35	97	65
TG-50	1314	2195	3508	36.9	64.4	0	4	100	96
SG-99	1256	2649	3905	21.6	65.6	9	19	91	81
K-1375	1480	2511	3991	36.5	69.4	12	25	88	75
ICR-48	1417	2448	3865	36.0	69.9	23	29	78	71
ICR-24	1410	2377	3788	37.0	68.8	14	20	86	80
ICGV-92121	1189	2975	4164	29.2	68.9	60	94	40	6
GG-2	1176	2573	3739	29.7	68.2	45	73	55	27
TG-26	899	1736	2654	38.2	65.4	76	87	24	13
GG-7	931	2337	3079	23.4	68.9	72	90	28	10
SEm±	109	210	265	2.3	1.3				
CD (P=0.05)	315	605	763	6.6	3.9				
Y									
SEm±	45	86	108	0.9	0.6				
CD (P=0.05)	129	247	312	2.7	1.6				
YxT									
SEm±	95	215	252	3.0	0.9				
CD (P=0.05)	266	603	707	8.5	2.5				

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Integrated nutrient management in sunflower, *Helianthus annuus* L. raised in rice-fallows of Tamil Nadu

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Abstract

Field experiments were conducted during *rabi* 2007 and *kharif* 2008 to study the maximization of sunflower productivity (*Helianthus annuus* L.) through integrated nutrient management in the coastal rice fallow system with the organic sources, *viz.*, vermicompost, enriched farm yard manure (FYM) in combination with inorganic nutrients and *Azospirillum*. The experimental results revealed that application of 100% recommended dose of NPK + vermicompost @ 5 t/ha + soil application of *Azospirillum* (T_9) gave the highest yield. The integrated application of organic and inorganic manure gave 29% higher yield than the recommended dose of NPK.

Key words: Sunflower, integrated nutrient management, vermicompost, enriched FYM, biofertilizer and NPK

Introduction

India, being one of the countries with large cultivated area under oilseeds in the world, has been chronically deficient in *per capita* supplies of fat and oils. One of the critical factors for low productivity of oilseeds is imbalanced use of plant nutrients. This necessitates judicious use of fertilizers and manures and adoption of appropriate agronomic practices. Vermicompost, which is produced by the fragmentation of organic wastes by earthworms, has a fine particulate structure and contains nutrients in forms that are readily available for plant uptake. In view of the escalating prices, high demand and supply gap of chemical fertilizers, there is a growing need to adopt integrated nutrient management (INM) by judicious combination of organic manures, inorganic and bio fertilizers to improve soil health and sunflower productivity (Kale *et al.*, 1992). In this context, INM holds great promise in meeting the growing nutrient demands of intensive agriculture and maintaining the crop productivity at a fairly high level. Hence, the present investigation was taken up to develop an INM package for sunflower in rice fallows in the coastal deltaic areas of Tamil Nadu.

Materials and methods

Field experiments were carried out at experimental farm, Annamalai University, Annamalai Nagar during *rabi* 2007 and *kharif* 2008 to evaluate the integrated effect of organic manures, inorganic and biofertilizers on sunflower productivity in rice-fallows. The experimental soil had 207.5, 21.5 and 340.8 kg of available N, P_2O_5 and K_2O/ha with a pH of 7.6 and organic carbon of 0.62%. The treatments consisted of a combination of NPK, vermicompost, enriched FYM and biofertilizer applied at different times (Table 1). The treatments were replicated thrice in a randomized block design. Sunflower hybrid KBSH-1 was sown with a spacing of 60cm x 30cm during both the seasons.

The enriched FYM was prepared by incubating 750 kg FYM with the recommended level of single super phosphate for 1 month. As per the treatment schedule, enriched FYM @ 750 kg/ha was applied just before sowing and thoroughly incorporating into the soil. Nutrient content in the FYM, enriched FYM and vermicompost were 1.39, 6.24, 0.67; 0.72, 0.61, 0.81 and 1.85, 1.30, 0.55% N, P_2O_5 and K_2O, respectively.

The recommended dose of 90 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha was applied. Fertilizer N and K were applied in 3 equal splits at sowing, 25 and 55 days after sowing through urea and muriate of potash, respectively. The entire quantity of P was applied as basal, either through single super phosphate or enriched FYM depending upon the treatment schedule. Soil application of *Azospirillum* @ 2 kg/ha was done at the time of sowing as per the treatment schedule. Initial irrigation was given immediately after sowing of sunflower seeds with adequate care to avoid excess soaking of water. While life irrigation was given on fifth day after sowing and the subsequent irrigation was given as per the crop requirement. A total rainfall of 20 mm (2 rainy days) was received for *rabi* 2007 and 165 mm (9 rainy days) for *kharif* 2008. Growth and yield attributes were recorded at maturity stage.

Table 1 Effect of integrated nutrient management on growth and yield attributes of sunflower

Treatment	Plant height (cm)			Leaf area index			Drymatter production (kg/ha)			Capitulum diameter (cm)			Test weight (g)			Seed yield (kg/ha)		
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
T_1	140.39	150.60	145.5	1.06	1.37	1.2	2648	3105	2876.5	11.00	11.12	11.1	3.33	4.20	3.76	1067	1095	1081
T_2	139.82	149.82	144.8	0.96	1.25	1.1	1376	2981	2178.5	10.08	10.30	10.2	3.30	4.05	3.75	870	928	899
T_3	144.84	159.43	152.1	1.38	1.74	1.6	3465	3747	3606.0	13.12	14.12	13.6	3.42	4.33	3.87	1431	1458	1444
T_4	141.60	153.52	147.6	1.15	1.47	1.3	2834	3329	3081.5	11.94	12.46	12.2	3.36	4.26	3.81	1183	1234	1208
T_5	145.34	160.69	153.0	1.42	1.83	1.6	3468	3748	3608.0	13.42	14.24	13.8	3.43	4.34	3.88	1460	1490	1475
T_6	142.12	156.02	149.1	1.24	1.60	1.5	3086	3534	3310.0	12.46	13.23	12.8	3.39	4.30	3.84	1250	1411	1330
T_7	152.23	164.19	158.2	1.64	2.12	1.9	3952	3933	3942.5	14.94	15.86	15.4	4.13	4.61	4.37	1667	1689	1678
T_8	149.65	162.58	156.1	1.55	1.99	1.8	3835	3860	3847.5	14.18	15.09	14.6	4.01	4.47	4.24	1518	1540	1529
T_9	164.42	168.39	166.4	2.01	2.49	2.3	4192	4204	4198.0	16.72	17.65	17.2	4.50	5.00	4.75	2092	2120	2106
T_{10}	157.04	165.64	161.3	1.75	2.26	2.0	4062	4193	4127.5	15.64	16.85	16.2	4.32	4.74	4.53	1895	1951	1923
SEm±	0.42	0.76		0.04	0.04		137	167		0.27	0.30		0.01	0.01		16	17	
CD (P=0.05)	0.84	1.52		0.08	0.09		275	335		0.54	0.60		0.02	0.02		33	34	

T_1 - 100% RD of NPK/ha, T_2 - 75% RD of NPK/ha, T_3 - 100% RD + EFYM @ 750 kg/ha, T_4 - 75% RD + EFYM @ 750 kg/ha, T_5 - 100% RD + VC @ 5 t/ha, T_6 - 75% RD + VC @ 5 t/ha, T_7 - 100% RD + EFYM @ 750 kg/ha + soil application of *Azospirillum* @ 2 kg/ha, T_8 - 75% RD + EFYM @ 750 kg/ha + soil application of *Azospirillum* @ 2 kg/ha, T_9 - 100% RD + VC @ 5 t/ha + soil application of *Azospirillum* @ 2 kg/ha, T_{10} - 75% RD + VC @ 5 t/ha + soil application of *Azospirillum* @ 2 kg/ha; RD-Recommended dose; FYM-Farmyard manure; EFYM-Enriched farmyard manure; VC-Vermicompost

Results and discussion

Growth and yield attributes: The data pooled over the years (Table 1) indicated that growth and yield attributing characters of sunflower *viz.*, plant height, LAI, drymatter production, head diameter, test weight and seed yield were favourably influenced with the integrated use of organic manures and inorganic fertilizers. These characters were significantly higher with 100% recommended dose of NPK + vermicompost @ 5 t/ha + soil application of *Azospirillum* @ 2 kg/ha in comparison to other treatments. This was followed by (T_{10}) 75% recommended dose of NPK + vermicompost @ 5 t/ha + soil application of *Azospirillum* @ 2 kg/ha. Application of NPK increased plant vigour due to the synergistic and cumulative effect and production of photosynthates through increased leaf area and chlorophyll content of leaves (Bhowmik *et al.*, 1994). Vermicompost or earthworm casts were reported to possess biological factors *viz.*, gibberllins, cytokinin and auxins which play an important role in rooting and plant development that also facilitates easy availability of plant nutrients and uptake by crops as opined by Dodamani (1997). The differences in growth responses could be due to fundamental differences between the composting and vermicomposting processes which use quite different microbial communities, with composting tending to result in the release of mineral nitrogen in the ammonium form, whereas vermicomposting releases most of the nitrogen in the nitrate form, which is readily available for plant uptake. The use of organic amendments to soil has long been recognized as providing a more balanced and better timed source of nutrition for plant growth, through the gradual decomposition of the organic matter by microorganisms, and slower mineralization and release of nutrients that it contains. The favourable nutritional environment in the root zone thus created a conducive environment for sunflower crop to maximize its yield under rice-fallows (Krishnakumar and Vireshwar Singh, 1995 and Sankara Reddy *et al.*, 2000).

Seed yield: The sunflower crop responded well to additional application of vermicompost and *Azospirillum* combined with the recommended doses of NPK fertilizers. Application of vermicompost might have imparted distinct improvement in soil physical properties of texture, structure amalgamate of humified earthworm feces and organic matter, stimulated plant growth beyond that produced by mineral nutrients because of the effects of the humic substance present in the vermicomposts or due to plant growth regulators associated with the humic acids. In addition, the presence of plant growth influencing substances, such as plant growth hormones and humic acids in vermicomposts has also been suggested as a possible factor contributing to increased yield (Muscolo et al., 1999). Integrated application of 100% recommended dose of NPK + vermicompost @ 5 t/ha + soil application of *Azospirillum* @ 2 kg/ha (T_9) produced significantly higher mean seed yield of 2106 kg/ha due to the constant release of N from the organic manure vermicompost when supplemented with NPK fertilizers to satisfy the demand of the nutrients by the sunflower crop at all stages of growth. This has been responsible for obtaining higher seed yields of sunflower. The results are in agreement with the findings of Chinnamuthu and Venkatakrishnan (2001), Kademani et al. (2003) and Nandhagopal et al. (2003).

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Large-scale evaluation of Fruit boost and Bee-Q in enhancing the seed yield of sunflower, *Helianthus annuus* L.

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Abstract

Fruit boost, a queen mandibular pheromone based commercial bee attractant was evaluated on a field scale for the first time in India for its influence on pollinators visits and yield parameters of sunflower along with Bee-q, a food-based attractant during *rabi* season of 2002-03. Sunflower (cv. Agsun) was raised in an area of 2.4 ha, which was divided into three plots, each of 0.8 ha to accommodate three treatments namely, application of Fruit boost and Bee-q, and unsprayed which served as a control. Both attractants significantly enhanced the visits by *Apis dorsata*, *A. mellifera*, *A. cerana* and other pollinators up to 3 days after application. Application of Fruit boost was most beneficial with significantly highest yield of 1155 kg/ha followed by Bee-q (1002 kg/ha) accounting to an increase of 25.14 and 8.56% over control that yielded 923 kg/ha. Consequently, there was a net returns of Rs. 2390 and Rs. 635/ha due to spray of Fruit boost and Bee-q, respectively. Increase in the yield was obviously due to higher head weight, seed filling and seed weight. Application of bee attractant also had beneficial influence on seed germination, shoot length and seedling vigour.

Key words: Fruit boost, Bee-q, sunflower, honey bees, pollinators

Introduction

Sunflower being a highly cross-pollinated crop, adequate pollination is vital for any significant increase in seed production. Through good management practices yield levels can be increased to an extent of 45 to 60% (Melnichenko and Khalifman, 1960). The flowers produce abundant quantity of nectar and pollen which attract large number of honey bees. Bee pollination results not only in increase of yield but also improves their quality. However, if the bee density is low or the weather conditions are not suitable for bee activity or the crop is unattractive to the bees, pollination of the crop is adversely affected resulting in poor yields. Under such situations bee attractants which have received the attention of scientists and farmers worldwide, play a vital role in maximizing the bee visits on the target crop and thus ensuring optimum yield. Many commercial bee attractants like, Bee here, Bee scent, Bee scent plus, Bee-q and Fruit boost etc. have been employed at farm level in the United States of America, Canada, Australia and United Kingdom. Hence, the present studies were made on the field scale evaluation of two commercial bee attractants namely, Fruit boost and Bee-q for the first time in India, and the results are presented in this paper.

Materials and methods

This experiment was carried out during *rabi* season of 2002-03. Two commercial bee attractants namely, Fruit boost and Bee-q were obtained from Phero Tech Inc., Canada and Excel Industries Limited, India, respectively. Fruit boost is a queen mandibular pheromone-based attractant while Bee-q a food-based attractant. Sunflower (cv. Agsun) was raised in 2.4 ha by following the recommended package of practices. The crop was sprayed with HaNPV @ 250 LE/ha at flower initiation stage to manage *Helicoverpa armigera* Hub. The total cropped area of 2.4 ha was divided into three blocks each of 0.8 ha, thus each block representing a treatment, resulting in total of three treatments.

The treatments involved were as follows;

T_1 = Spray of Bee-q at 50% flowering @ 12.5 g/l
T_2 = Spray of Fruit boost at 50% flowering @ 1 ml/l
T_3 = Control (no spray)

Six colonies each of *A. mellifera* and *A. cerana* were kept in the centre of the cropped area at 10 % flowering of the crop. In each treatment, eight spots were selected randomly which were considered as eight replications and observations on different pollinators (*Apis dorsata* F., *A. mellifera* L., *A. cerana* F. and other pollinators) visitation was made on five flower heads from each spot. Observations were made a day before spray of attractants and 1, 2, 3, 4 and 5 days after spray at 0800 h, 1000 h, 1500 h and 1700 h of the day. The observation means of different hours of the day were pooled for different species of pollinators and subjected to +1 transformation and then to 't' test using MSTATC programme. Duration of the time spent by *A. mellifera* on sunflower head was recorded by observing 5 flowers in each replication of the treatment during their peak active periods and such observation means were later subjected to 't' test. Observations were also made on the yield parameters *viz.*, head weight, number of filled and unfilled rows/head, filled and unfilled seeds/head, weight of filled and unfilled seeds, per cent chaffiness, 100 seed weight and seed yield. Qualitative parameters like oil content, per cent germination of seeds, shoot and root length, and seedling vigour were also recorded.

Results and discussion

Influence on pollinators visits: The pollinators that visited sunflower heads were *Apis mellifera* L., *A. cerana* F., *A. dorsata*, non *Apis* bees and other insects

Observations made on a day prior to the application of Fruit boost and Bee-q revealed no differences in pollinators' visitation among the treatments (Table 1). However, a day after the spray of attractants, Fruit boost and Bee-q treated crop attracted significantly more pollinators (6.31 and 6.25 pollinators/5 flowers/min) than the control (5.65 pollinators). Similar trend was observed on second and third day after spraying of attractants. Both the commercial attractants were equally effective on the first three days after application. But on fourth day only, Fruit boost was able to attract more pollinators (5.63 pollinators) than Bee-q and control. Fruit boost was as good as control on the fifth day.

Efficacy of Fruit boost in enticing higher pollinators to sunflower could be attributed to the presence of queen mandibular gland pheromone that stimulates the foraging activity of workers. Increased recruitment induced by queen pheromone sprays on the crop could operate by heightening perceptions of foragers by way of an increase in number of dance circuits ultimately resulting in longer waggle dance.

A. mellifera bees stayed significantly for longer time on flowers consequent to the application of Fruit boost and Bee-q up to two days after spraying (Table 2). Bee-q was able to retain its superiority over control up to the third day also. However, both attractants were as good as control four days after application.

Influence on quantitative parameters: Influence of spraying of attractants on quantitative yield parameters is presented in tables 3 and 4. Fruit boost and Bee-q sprayed treatments significantly increased the head weight to the tune of 28.42 and 18.88 % over control. Fruit boost sprayed treatment enhanced the filled seed rows significantly by 7.14 % where as Bee-q spraying was as good as control. Increase in filled seed rows was obviously attributed to visiting of more pollinators and also more time spent on the sprayed crop which has ensured adequate pollination. There was no variation in unfilled seed rows among the treated and control plots.

However, filled seed weight was significantly enhanced by spray of Fruit boost and Bee-q to the tune of 40.29 and 21.39 % respectively, over control. There was no impact on unfilled seed weight, per cent chaffiness among various treatments.

Fruit boost sprayed treatment recorded significantly heavier seeds (4.66 g vs. 4.38 g/100 seeds in control) resulting in an increase by 6.39% over control. But application of Bee-q did not enhance the seed weight significantly over the control. Heavier seeds from Fruit boost sprayed treatment is attributed to the higher number of pollinators attracted to treated heads, more time spent by bees and the vigorous pollen received by such heads ultimately increasing the weight of seeds.

Spray of Fruit boost produced significantly highest yield of 1155 kg/ha followed by Bee-q (1002 kg/ha). Crop which did not receive attractants produced lowest yield of 923 kg/ha. Thus, application of Fruit boost and Bee-q enhanced yield by 25.14 and 8.56%. Results of these studies emphasize that application of attractants can increase yield of sunflower due to increase in activity of the pollinators causing deposition of pollen on to stigma at right time. Higher efficacy of Fruit boost could be attributed to the cumulative effect of enhanced pollinators' visitation and more time spent on the flowers which ultimately resulted in enhancement of seed yield. Increased sunflower yield due to honey bee pollination is also reported by many workers (Bhosle *et al.*, 1992 and Williams, 2001) and the present results also endorse these reports.

An incremental benefit of Rs. 2390 was obtained from Fruit boost sprayed treatment and Rs. 635 from Bee-q sprayed treatment. Present findings corroborate the earlier reports of Winston and Slessor (1993) who reported increase in benefits up to 60 % due to spray of Fruit boost and other bee attractants on Fruit crops and sunflower.

Influence on qualitative parameters: The effect of spray of Fruit boost and Bee-q is presented in table 5. There was no significant variation among various treatments in oil content. It is likely that oil content depends on genetic factors rather than pollinators' visitation in sunflower. However, seeds obtained from the Fruit boost sprayed treatment exhibited 5.25% increase in germination compared to 4.02% increase in Bee-q treatment over control. Root length was unaffected by the spray of attractants whereas, shoot length was significantly increased by 24.28% due to spray of Fruit boost. Consequently, there was significant increase in seedling vigour due to spray of Fruit boost to the tune of 30.43% over control while it was nonsignificant in Bee-q sprayed plot (6.85%).

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Table 1 Influence of Fruit boost and Bee-q on total pollinators' visitation on sunflower

Treatment	Number of pollinators*/5 flowers/min.					
	1 DBS	1 DAS	2 DAS	3 DAS	4 DAS	5 DAS
Crop sprayed with Fruit boost @ 1 ml/l	5.25	6.31	6.25	5.81	5.63	5.44
Crop sprayed with Bee-q @ 12.5 g/l	5.31	6.25	6.19	5.94	5.44	5.38
Crop without any spray (Control)	5.19	5.65	5.38	5.19	5.25	5.31
't' value						
Significance (comparison between 1 & 3)	NS	3.0728*	4.5066*	3.1954*	2.9795*	NS
Significance (comparison between 2 & 3)	NS	3.2070*	3.5885*	3.7971*	NS	NS
Significance (comparison between 1 & 2)	NS	NS	NS	NS	NS	NS

* *Pollinators included: Apis dorsata; A. mellifera; A. cerana* and other pollinators; NS = Non-significant;
* = Significant at 0.05 level; DBS = Days before spraying; DAS = Days after spraying

Table 2. Average time spent by *Apis mellifera* on sunflower heads

Treatment	Time spent by one bee/flower (min)					
	1 DBS	1 DAS	2 DAS	3 DAS	4 DAS	5 DAS
Crop sprayed with Fruit boost @ 1 ml/l	0.37	0.43	0.47	0.43	0.39	0.36
Crop sprayed with Bee-q @ 12.5 g/l	0.39	0.45	0.51	0.48	0.40	0.37
Crop without any spray (Control)	0.36	0.30	0.34	0.36	0.34	0.35
't' value						
Significance (comparison between 1 & 3)	NS	3.0569*	2.5901*	NS	NS	NS
Significance (comparison between 2 & 3)	NS	2.7205*	3.1189*	2.9775*	NS	NS
Significance (comparison between 1 & 2)	NS	NS	NS	NS	NS	NS

NS = Non-significant; * = *Significant at 0.05* level; DAS = Days after spraying; DBS = Days before spraying

Table 3 Influence of Fruit boost and Bee-q on yield components of sunflower

Treatment	Head weight (g)	% increase over control	Filled rows	% increase over control	Unfilled rows	% decrease over control	Filled seed weight (g)	% increase over control	Unfilled *seed* weight (g)	% decrease *over* control
Crop sprayed with Fruit boost @ 1 ml/l	87.62	28.42	30.00	7.14	4.28	22.18	56.48	40.29	1.55	26.19
Crop sprayed with Bee-q @ 12.5 g/l	81.11	18.88	28.90	3.21	4.67	15.09	48.87	21.39	1.85	11.90
Crop without any spray (Control)	68.23		28.00		5.50		40.26		2.10	
't' values										
Significance (comparison between 1 & 3)	3.3664*		2.0000*		NS		3.5027*		NS	
Significance (comparison between 2 & 3)	2.4288*		NS		NS		2.2731*		NS	
Significance (comparison between 1 & 2)	NS		NS		NS		NS		NS	

NS = Non-significant; * = Significant at 0.05 level

Table 4 Influence of Fruit boost and Bee-q on yield components of sunflower

Treatment	% chaffiness	% decrease over *control*	100-seed *weight (g)*	% increase over control	Seed yield (kg/ha)	*% increase* over control	Incremental benefit cost returns (Rs./ha)
Crop sprayed with Fruit boost @ 1 ml/l	24.07	8.06	4.66	6.39	1155	25.14	3480
Crop sprayed with Bee-q @ 12.5 g/l	21.96	16.12	4.58	4.57	1002	8.56	1185
Crop without any spray (Control)	26.18		4.38		923		
't' values							
Significance (comparison between 1 & 3)	NS		2.5200*		2.3421*		
Significance (comparison between 2 & 3)	NS		NS		4.9735*		
Significance (comparison between 1 & 2)	NS		NS		2.3421*		

* - Significant at 0.05 level; Price of sunflower seeds (Rs. 1500/q); NS- Non-significant

Table 5 Influence of Fruit boost and Bee-q on qualitative parameters of sunflower

Treatment	Oil percentage	% increase over control	% germination	% increase over control	Root length (cm)	% increase over control	Shoot length (cm)	% increase over control	Vigour index	% increase over control
Crop sprayed with Fruit boost @ 1 ml/l	40.04	0.03	94.20	5.25	1506	[illegible]	11.67	24.28	2669.50	30.43
Crop sprayed with Bee-q @ 12.5 g/l	40.16	0.32	93.10	4.02	1383	[illegible]	9.67	2.98	2187.00	6.85
Crop without any spray (Control)	40.03		89.50		1350		9.39		2046.70	
't' values										
Significance (comparison between 1 & 3)	NS		6.622*		NS		2.844*		2.2583*	
Significance (comparison between 2 & 3)	NS		5.3719*		NS		NS		NS	
Significance (comparison between 1 & 2)	NS		NS		NS		NS		NS	

*- Significant at 0.05 level ; NS- Non-significant

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Effect of genotype and mutagen dose on induced variability for resistance to *Alternaria* leaf blight in sunflower, *Helianthus annuus* L.

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Abstract

Four diverse genotypes ISL-025, ISL-026, Morden and 180-08 were treated with 20 and 30 Kr of gamma rays to induce genetic variability for tolerance to *Alternaria* leaf blight in sunflower. Significant variability was observed in disease index in M_2 and subsequent generations in all the treatments. In general, the higher dose produced lower mean percent disease index (PDI) scores and higher variability at all the three stages of disease scoring. There were also significant variations in the response of genotypes to mutagenic treatments. In general, the progenies derived from mutagenic treatments of genotypes ISL-025 and ISL-026 had lower PDI values compared to Morden and 180-08. The genotypes with higher level of tolerance produced more number of progenies with low PDI scores. A number of progenies in M_4 and M_5 generations showed significantly lower PDI values over the check Morden. There was significant improvement in the resistance of the progenies derived through mutagenic treatment. Twenty-two progenies showed not only lower PDI values but also superior seed yield over check.

Key words: Mutation, *Alternaria* leaf blight, resistance, *Helianthus annuus* L., variability

Introduction

Sunflower (*Helianthus annuus* L.) was introduced to India, in early 1970s and within a short time it occupied a significant area in the country. Presently, it is grown over an area of 2.07 m.ha. producing 1.25 m.t. with average productivity of 604 kg/ha (Anonymous, 2004). Concomitant with increase in area and production in the country, there has been an increased incidence and severity of sunflower diseases also. *Alternaria* leaf blight caused by *Alternaria helianthi* (Hansf.) Tubaki and Nishihara has been considered as a potentially destructive disease in India and elsewhere, causing more than 80% of yield loss under severe disease conditions (Hiremath *et al.*, 1990). In-built genetic resistance would be the most economic means of reducing yield losses in sunflower. However, studies so far indicated that high degree of resistance to *Alternaria helianthi* is not reported in *Helianthus* species (Shobharani and Ravikumar, 2003). Only partial resistance is available in the sunflower gene pool which is reported as polygenic(Ravikumar *et al.*, 1995). The usefulness of such resistance to develop resistant varieties/hybrids for commercial exploitation is uncertain. Further, *Alternaria* leaf and stem blight resistance appears to be additive and only moderate gains can be expected by selection (Kong *et al.*, 1996). Therefore, induced mutations were proposed to develop high level of resistance to leaf blight in sunflower (Kong e *al.*, 1996). A large number of genotypes resistant to funga diseases have been developed through induced mutation in different crops such as wilt in cotton (Bazhanova *et al.* 1990), *Cercospora* leaf spot and rust in groundnut (Patil e *al.*, 1995). However, it is not easy to detect mino polygenic changes for quantitative traits. In the presen experiment, four genotypes were treated with mutage and selections were made in M_2 and subsequen generations to confirm the resistance.

Materials and methods

The present investigation was carried out at Mair Agricultural Research Station, University of Agricultura Sciences, Dharwad, Karnataka, India over six season from 1999 to 2003. Dharwad is a hot spot for *Alternari* leaf blight of sunflower particularly during rainy seaso with more number of rainy days, moderate temperature and high humidity prevailing throughout the rainy seasons

Four diverse genotypes *viz.*, ISL-025, ISL-026, Morde and 180-08, were selected for this study. ISL-025 an ISL-026 were interspecific derivatives of *H. petiolaris* an *H. argophyllus* respectively, while Morden is a popula variety and 180-08 is a breeding line. About 500 seed from each of these four genotypes were exposed t gamma ray treatment at Nuclear and Agriculture Division BARC, Trombay, Mumbai. The M_1 generation was grow during summer 1999 and all the plants were selfed. Equa quantity of seeds from all the plants in each treatmen were mixed to form M_2 generation. Each M_2 populatio was grown in a plot size of 20 m x 4.5 m during *khari* 2000. About 150-175 superior plants from each M_2 wer scored for PDI as given below. From the plants scored 30-40 plants for each M_2 were selected to grow M progenies. The plant to row progenies (M_3) of selected plants were grown during summer 2000 and the best plants of individual progenies were selfed during post rainy 2000 to advance them to the M_4 generation. Altogether 227 M_4 progenies from seven treatments were evaluated during *kharif* 2001 in three replications. Each progeny was grown in a row length of 4m. Five plants/progeny/replication were selected for recording observations on PDI at 3 stages as given below along with seed yield/plant. Further, five uniform plants in each progeny were selfed for advancing to M_5 generation. The M_5 progenies were tested for disease reaction at three stages and seed yield in three replications during *kharif*, 2002.

Data on disease severity was assessed using 0-9 scale and PDI was calculated as given below (Mayee and Datar, 1986).

$$\text{PDI} = \frac{\Sigma \text{ Observations}}{\text{No. of observations x Maximum grade value}} \times 100$$

The data collected on different M_2 populations was subjected for statistical analysis. Genetic parameters such as mean, range, variance and coefficient of variation (CV) were calculated. The phenotypic and genotypic coefficient of variation (PCV and GCV), heritability, genetic advance as percent of mean (GAM) were calculated in M_4 and M_5 progenies. Further, the variation was partitioned into total mutants and genotypes. The variation in genotypes was again partitioned into three components *viz.*, mutation doses (20 and 30 kr) and interaction components (Sharma, 1998).

Results and discussion

Attempt to identify sources of resistance to *Alternaria* leaf blight in *Helianthus* species had revealed only partial resistance controlled by polygenic system. As high level of resistance is not available in cultivated gene pool, attempt was made to induce variability for resistance through mutations. The frequency and spectrum of mutations reported for quantitative traits including seed yield in several crops attracted attention of sunflower workers. A large number of genotypes resistant to fungal diseases have been developed through mutations in different crops such as wilt in cotton (Bazhanova *et al.*, 1990), *Cercospora* leaf spot and rust in groundnut (Patil *et al.*, 1995). The present study elucidates the usefulness of physical mutagens inducing variation for resistance to *Alternaria helianthi* in sunflower. Further, the study also generate information on effectiveness of mutagen on four genotypes.

The effect of polygenic mutations for quantitative characters was studied in M_2 generation in the form of their mean, range, variance and CV.

The mean PDI for *Alternaria* leaf blight was decreased with increase in dosage of gamma rays at all the three stages (Table 1). Among M_2 populations, the highest mean PDI was observed in 180-08 (20 kr) and the least was in ISL-026 (30 kr) in all the three stages. The CV was also increased with increase in dosage. The CV was highest in ISL-026 (30 kr), while it was least in 180-08 (20 kr). The above findings are also in accordance with the findings of Yadav *et al.* (2001), who observed decrease in mean PDI and increase in variability with increased dose of mutagen against *Alternaria brassicae* in mustard. Overall, ISL-026 (30 kr) and ISL-025 (30 kr) exhibited low disease mean among seven M_2 populations. Among the genotypes, ISL-025 and ISL-026 had lower mean values in their M_2 compared to other genotypes. Such genotypic differences for mutagenic treatment has been reported earlier in sunflower and other crops (Venkatachalam and Jayabalan, 1997). In mutation breeding programme particularly for a specific trait like disease resistance, the choice of genotype to be treated is very important since different genotypes differ in their response to disease and mutagenic treatments. It is reported that the moderately resistant genotypes produce higher frequency of resistant mutants compared to susceptible ones. Therefore, it is suggested to use moderately tolerant genotypes for mutation instead of susceptible genotypes for generating desirable variability for resistance. Higher dose of mutagen produce more variability in sunflower (Yadav *et al.*, 2001).

Two hundred and twenty seven M_4 progenies were selected from all the seven treatments. The analysis of variance indicated significant differences among the progenies at all the three stages of disease scoring suggesting significant variability among the progenies. The progenies of individual treatments also showed significant variability for PDI at all the stages in both M_4 and M_5 generations except in progenies of 180-08 (20 kr), which was non-significant in M_4 (Table 2). It is evident from the results that the mean PDI of the progenies derived through mutations was lower than the check Morden in both M_4 and M_5 generations. For example, the mean PDI of total mutants was 15.2 as against 24.4% in check variety Morden at stage-I. Similarly, at stage-II it was 45.2 against 46.6% and at stage-III it was 73.6 against 78.8% in check in M_4 generation (Table 3). Such improvement in resistance of the progenies due to mutagenic treatment has been reported in other crops also (Pathirana, 1992; Yadav *et al.*, 2001).

The analysis of mutagenic doses indicated in general the higher dose produced lower mean PDI scores and higher GCV and PCV value at all the three stages. Therefore, it is desirable to use 30 kr gamma irradiation instead of 20 kr. Similarly, the progenies derived from mutagenic treatments of ISL-026 (30 kr) and ISL-025 (30 kr) had lower mean PDI values compared to Morden and 180-08 in M_4 and M_5 generations (Tables 3, 4). The sensitivity of the genes to mutagenic treatment also depends on the genetic background (Smutkupt *et al.*, 1988). Further, the polygenic traits depend on many component traits and alterations could be at different component level. The genotypes may vary for their component traits leading to differential response for the same mutagenic treatment. Similar to the M_2 generation, the genotypes ISL-026 and ISL-025 which produced all the progenies with low scores leading lower mean PDI compared to Morden.

Table 1 Genetic variability parameters for per cent disease index (PDI) in M_2 progenies of sunflower

Character	Treatment	Mean	Range	Variance	CV
PDI at flowering	180-08-20Kr	27.3	13.3-32.2	10.8	12.0
	180-08-30Kr	24.6	11.1-31.1	20.0	18.2
	Morden-20Kr	24.6	14.4-33.3	25.0	20.3
	Morden-30Kr	22.6	11.1-32.2	36.7	26.8
	ISL-025-20Kr	23.7	13.3-31.1	29.6	22.9
	ISL-025-30Kr	22.2	12.2-28.9	31.5	25.2
	ISL-026-30Kr	21.2	3.3-21.1	32.9	27.0
PDI at 15 days after flowering	180-08-20Kr	77.1	44.4-87.6	70.3	10.8
	180-08-30Kr	70.1	42.2-84.4	110.0	14.9
	Morden-20Kr	69.0	44.4-85.5	112.1	15.3
	Morden-30Kr	68.0	47.7-86.6	109.7	15.3
	ISL-025-20Kr	68.6	46.6-86.6	137.5	17.0
	ISL-025-30Kr	66.9	45.5-84.4	165.0	19.2
	ISL-026-30Kr	64.8	38.8-81.1	170.3	20.1
PDI at physiological maturity	180-08-20Kr	93.8	72.2-98.8	16.2	4.3
	180-08-30Kr	89.6	81.1-97.7	39.8	7.0
	Morden-20Kr	87.7	71.1-98.8	36.0	6.8
	Morden-30Kr	87.2	71.1-96.6	27.8	6.0
	ISL-025-20Kr	88.4	68.8-97.7	42.6	7.3
	ISL-025-30Kr	86.4	72.2-95.5	33.6	6.7
	ISL-026-30Kr	84.6	71.1-96.6	33.6	6.8

CV = Coefficient of variation

Table 2 Analysis of variance for per cent disease index (PDI) in M_4 and M_5 progenies of sunflower

S.No.		Treatment	d.f.	MSS for the character					
				M_4 progenies			M_5 progenies		
				PDI at 50% flowering	PDI at 15 days after 50% flowering	PDI at physiological maturity	PDI at 50% flowering	PDI at 15 days after 50% flowering	PDI at physiological maturity
1.		Total mutants	226	47.9**	158.6**	116.7**	64.2**	141.7**	103.1**
2.		180-08 (20+30kr)	33	24.7**	37.8**	19.5**	24.0**	41.6**	31.5**
	a	180-08 (20Kr)	9	17.4	49.3	17.3	20.6**	40.7**	27.2**
	b	180-08 (30Kr)	23	21.8**	27.3**	19.8*	24.2**	23.3**	23.3**
	c	20 Kr vs 30 Kr	1	156.0**	176.4**	34.3	47.3**	471.6**	260.4**
3.		Morden (20+30Kr)	74	34.1**	82.1**	50.2**	35.0**	81.2**	46.7**
	a	Morden (20Kr)	34	27.1**	26.1**	33.1**	26.5**	32.6**	30.7**
	b	Morden (30Kr)	39	26.2**	35.2**	50.7**	27.7**	41.0**	49.6**
	c	20Kr vs 30Kr	1	578.2**	3816.8**	613.2**	610.3**	3295.2**	481.7**
4.		ISL-025 (20+30Kr)	74	28.4**	64.3**	40.7**	34.9**	46.9**	59.7**
	a	ISL-025 (20Kr)	33	27.5**	22.3**	22.6**	36.9**	22.2**	37.4**
	b	ISL-025 (30Kr)	40	25.8**	25.5**	33.1**	27.2**	29.7**	42.2**
	c	20 Kr vs 30 Kr	1	162.3**	2999.4**	944.9**	276.5**	1550.3**	1496.2**
5.		ISL-026 (30Kr)	42	25.0**	27.9**	69.0**	15.5**	31.7**	85.2**

** = Significant at 1 per cent level; * = Significant at 5 per cent level

Table 3 Genetic variability parameters for per cent disease index (PDI) at different stages of M_4 and M_5 progenies of sunflower

Character	Treatment	No. of progenies	M_4 Generation			M_5 Generation		
			Mean	PCV	GCV	Mean	PCV	GCV
	Total mutants	227	15.2	28.7	24.9	22.7	21.1	GCV
PDI at 50% flowering	180-08-20Kr	10	22.2	16.4	8.8	29.4	9.8	19.8
	180-08-30Kr	24	17.5	18.8	13.2	28.6	9.9	8.3
	Morden-20Kr	35	18.2	20.7	13.8	25.9	13.4	8.5
	Morden-30Kr	40	15.0	22.5	18.0	22.6	14.7	10.3
	ISL-025-20Kr	34	16.0	21.7	17.2	23.0	16.4	12.6
	ISL-025-30Kr	41	14.3	22.0	19.3	20.8	15.2	14.5
	ISL-026-30Kr	43	10.0	32.1	27.0	17.0	15.1	14.0
	Check		24.4			36.5		12.3
	Total mutants	227	42.2	17.9	16.8	45.2	15.6	
PDI at 15 days after 50% flowering	180-08-20Kr	10	54.2	10.5	5.2	58.2	8.0	14.9
	180-08 30Kr	24	51.4	7.7	4.6	54.3	5.4	5.2
	Morden-20Kr	35	48.8	7.4	5.2	50.9	7.0	4.7
	Morden-30Kr	40	40.5	9.5	7.8	43.3	9.4	6.1
	ISL-025-20Kr	34	44.4	7.2	5.4	46.8	6.9	8.0
	ISL-025-30Kr	41	37.1	9.2	7.0	41.6	8.4	5.1
	ISL-026-30Kr	43	32.6	10.8	8.5	36.3	9.8	7.1
	Check		46.6			63.4		8.4
	Total mutants	227	73.6	9.0	8.1	76.1	8.1	
PDI at physiological maturity	180-08-20Kr	10	78.8	4.5	1.8	77.0	4.5	7.4
	180-08-30Kr	24	77.6	4.6	2.3	81.3	3.6	3.5
	Morden-20Kr	35	78.3	4.9	3.8	79.9	4.6	3.1
	Morden-30Kr	40	75.0	6.5	4.8	76.9	5.8	3.6
	ISL-025-20Kr	34	76.3	4.4	3.0	79.8	5.5	4.9
	ISL-025-30Kr	41	72.1	5.5	4.0	74.6	5.5	3.7
	ISL-026-30Kr	43	63.0	8.5	7.1	67.4	8.2	4.7
	Check		78.8			79.7		7.7

Table 4 Superior M_6 mutant lines for *Alternaria* leaf blight resistance and seed yield in sunflower

Treatment	Number of mutant lines superior over check								Superior mutant lines for disease and seed yield in both M_4 and M_5 generations
	PDI at 50% flowering		PDI at 15 days after 50% flowering		PDI at physiological maturity		Seed yield (g)		
	M_4	M_5	M_4	M_5	M_4	M_5	M_4	M_5	
180-08-20Kr	9	10	-	2	-	2	-	-	—
180-08-30Kr	19	15	6	12	4	10	-	-	—
Morden-20Kr	11	35	9	30	8	11	4	6	26,38,102 and107
Morden-30Kr	40	40	19	40	15	10	7	9	1,13,43,87,122 and143
ISL-025-20Kr	32	34	15	34	30	8	2	6	57 and115
ISL-025-30Kr	41	41	21	41	41	41	7	11	66,90,91,92,155,158 and 165
ISL-026-30Kr	43	43	43	43	43	43	8	8	46,52 and 79

Inherently the genotypes Morden and 180-08 are more susceptible compared to ISL-025 and ISL-026. Therefore, it can be inferred that for a polygenic trait like *Alternaria helianthi* resistance, the genotypes with lower PDI values produce more number of progenies with lower PDI values compared to the genotypes with higher susceptibility upon mutation. Hence, it is suggested to use the genotypes with higher level of resistance for mutation to improve resistance to *Alternaria* leaf blight in sunflower. Hundred and fourteen progenies showed consistently lower disease values compared to popular check Morden at all the three stages in both M_4 and M_5 generations. From this study, 22 mutant lines were identified with combination of low PDI values and high seed yield. The lines are four progenies of Morden (20 kr), six progenies of Morden (30 kr), two progenies of ISL-025 (20 kr), seven progenies of ISL-025 (30 kr) and three progenies of ISL-026 (30 kr) (Table 4). The lines are fairly homozygous and true breeding. Hence these lines can be utilized in the leaf blight resistance breeding programmes of sunflower. They may also form the base material for synthesizing leaf blight resistant populations for further improvement.

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Components of genetic variance and degree of dominance for seed yield attributing traits in sesame, *Sesamum indicum* L.

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Abstract

An experiment was conducted with six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of five inter-varietal crosses, TMV 4 x KS99037 (C_1) TMV 4 x KS990812 (C_2), TMV 4 x KS990813 (C_3), TMV 4 x KS99153 (C_4) and TMV 4 x Cordebergea (C_5) to study the components of variance and degree of dominance for days to first flowering, days to maturity, plant height, primary branches, capsules/plant, capsule length, seeds/capsule, 100 seed weight and seed yield/plant. The degree of dominance was greater than unity in TMV 4 x KS99153 for days to first flowering, seeds/capsule and 100 seed weight, TMV 4 x KS 990812 for capsules/plant and TMV 4 x KS 990813 for 100 seed weight indicating over dominance for the respective traits. Hence, it is suggested for adoption of heterosis breeding for these crosses in sesame. The traits, plant height, number of branches/plant and seed yield/plant were largely controlled by both additive and non-additive genetic variance. The pedigree or recombination breeding followed by selection in later generations would improve these characters. The traits, capsules/plant and capsule length were controlled by additive genetic variance, simple selection or simple recurrent selection would be effective in these crosses for these traits. The environmental variance for capsules/plant, capsule length, seeds/capsule and 100 seed weight revealed that the environment factors play an important role in the expression of these traits.

Key words: Sesame, components of variance, degree of dominance

Introduction

Sesame occupies a place of prominence among oilseeds, but its production has been relatively low as compared to other oilseed crops. The major constraints identified for most of the countries including India are, instability in yield, lack of wider adaptability, drought, non -synchronous maturity etc. For breaking such yield barrier of sesame and evolving varieties with high yield potential, it is desirable to combine the genes from genetically diverse parents. The success in identifying such parents mainly depends on the gene action that controls the trait. The choice of plant breeding methodology for upgrading the yield potential largely depends on the availability of reliable information on the nature and magnitude of gene effects present in the population. The developments in statistical genetics have made possible to study the various facets of quantitative genes and to use this information in formulating appropriate breeding strategy to effect genetic improvement of a particular trait. The present study, therefore, was aimed at studying the genetics of important quantitative characters including seed yield, so as to formulate suitable breeding strategy.

Materials and methods

The experimental material consists of six generations, *viz.*, P_1, P_2, F_1, F_2, BC_1 and BC_2 derived from five inter-varietal crosses TMV 4 x KS99037 (C_1) TMV 4 x KS990812 (C_2), TMV 4 x KS990813 (C_3), TMV 4 x KS99153 (C_4) and TMV 4 x Cordebergea (C_5), were raised at Department of oilseeds, Tamil Nadu Agricultural University, Coimbatore during *rabi* 2004. The parents and F_1s were planted in four rows of 6 m length. The BC_1 and BC_2 were planted in 6 rows of 7m length, while the F_2 of each crosses were raised in 12 rows of 7m length. The inter and intra row spacing was maintained at 30 cm x 30 cm. Recommended agronomic practices and plant protection measures were adopted to raise a successful crop. Fifty plants each from parents and F_1s, 100 plants from BC_1 and BC_2 generations and 250 plants from F_2 populations were randomly selected for recording various observations (Table 1). The variances estimated from different generations were partitioned into different genetic components of variation following Mather and Jinks (1977).

Results and discussion

The variance due to environment was lower than the additive and dominance variance in all the five crosses for days to maturity; C_1, C_2 and C_5 for days to first flowering; all crosses except C_1 for plant height; C_2, C_3 and C_4 for number of branched/plant and C_2 and C_3 for 100 seed weight. Hence, these crosses were not much influenced by the environment. The days to first flowering showed positive additive variance for all the crosses except C_3 (Table 1) and high dominance variance in all the five crosses.

Table 1 Estimates of various genetic components of variance for different characters in sesame

Cross	EW	D	H	F	[H / D]½
Days to first flowering					
TMV 4 x KS99037	11.77	28.28	-48.48	8.94	-
TMV 4 x KS990812	10.60	50.44	-67.92	-0.64	-
TMV 4 x KS990813	6.90	-2.28	13.04	-4.2	-
TMV 4 x KS99153	13.35	2.44	29.32	-0.74	3.47
TMV4xCordebergea	9.4	29.14	-55.36	-0.21	-
Days to maturity					
TMV 4 x KS99037	39.69	125.42	-191.16	34.17	-
TMV 4 x KS990812	35.37	-79.76	222.68	-117.32	-
TMV 4 x KS990813	22.59	-59.5	132.24	-19.71	-
TMV 4 x KS99153	36.83	-41.3	167.56	16.33	-
TMV4 x Cordebergea	24.01	85.66	-163.12	-4.43	-
Plant height					
TMV 4 x KS99037	242.10	-71.8	-63.24	68.44	0.94
TMV 4 x KS990812	183.17	287.52	-262.32	-27.18	-
TMV 4 x KS990813	235.43	-564.07	-302.64	-162.88	0.73
TMV 4 x KS99153	266.12	-688.9	1430.96	122.51	-
TMV4 x Cordebergea	482.13	933.28	-2587.64	-4.8	-
Number of branches/plant					
TMV 4 x KS99037	2.45	-1.0	6.12	0.7	-
TMV 4 x KS990812	2.41	-5.82	15.44	-1.83	-
TMV 4 x KS990813	2.44	7.84	-7.12	-2.12	-
TMV 4 x KS99153	2.56	-8.04	19.36	2.58	-
TMV4 x Cordebergea	2.87	0.66	-0.44	-3.05	-
Number of capsules/plant					
TMV 4 x KS99037	902.07	-298.05	313.36	-109.96	-
TMV 4 x KS990812	819.52	318.5	867.36	88.85	1.65
TMV 4 x KS990813	820.63	1786.42	-2463.04	-604.05	-
TMV 4 x KS99153	849.01	451.4	-334.72	78.6	-
TMV4 x Cordebergea	854.14	2031.34	-3287.6	232.35	-
Capsule length					
TMV 4 x KS99037	0.63	0.14	-0.14	-0.014	-
TMV 4 x KS990812	0.114	0.10	-3.8	0.05	-
TMV 4 x KS990813	0.05	0.20	-0.22	0.01	-
TMV 4 x KS99153	0.061	-0.048	0.068	-0.052	-
TMV4 x Cordebergea	0.063	-0.05	0.036	0.007	-
Number of seeds/capsule					
TMV 4 x KS99037	63.35	0.9	117.4	-56.43	11.42
TMV 4 x KS990812	67.42	34.48	-68.56	-51.76	-
TMV 4 x KS990813	68.13	66.1	-70.48	35.29	-
TMV 4 x KS99153	76.05	0.88	-64.92	-21.92	-
TMV4 x Cordebergea	82.41	-151.96	237.24	68.52	-
100 seed weight (g)					
TMV 4 x KS99037	0.003	-0.001	-0.001	0.0001	1.00
TMV 4 x KS990812	0.005	-0.28	0.59	0.1500	-
TMV 4 x KS990813	0.0023	0.0038	0.0076	-0.0007	1.41
TMV 4 x KS99153	0.002	-0.001	0.004	-0.001	-
TMV4 x Cordebergea	0.0021	0.0006	-0.0024	-0.0013	-
Seed yield/plant					
TMV 4 x KS99037	1.03	2.94	-1.64	0.11	-
TMV 4 x KS990812	1.76	-1.92	5.0	-2.5	-
TMV 4 x KS990813	2.14	-2.54	6.28	-2.17	-
TMV 4 x KS99153	1.83	1.6	-34.48	-0.68	-
TMV4 x Cordebergea	1.90	-1.32	0.72	-0.38	-
Oil content (%)					
TMV 4 x KS99037	48.04	-97.58	41.12	-36.57	-
TMV 4 x KS990812	16.56	-62.2	133.84	17.0	-
TMV 4 x KS990813	19.17	35.4	-66.2	-4.68	-
TMV 4 x KS99153	17.21	-45.2	92.48	-20.18	-
TMV4 x Cordebergea	30.64	47.06	-122.08	0.63	-

E - Non heritable variance due to environment; D-Fixable variance due to additive genes; H- Non fixable variance due to dominance; F-Co variance of additive and dominance effects; H / D]½ - Dominance ratio

Besides, the additive variance was positive in C_1 and C_5 for days to maturity; C_2 and C_5 for plant height; C_3 and C_5 for number of branches/plant and 100 seed weight; all the crosses except C_1 for number of capsules/plant; C_1, C_2 and C_3 for capsule length; all the crosses except C_5 for number of seeds/capsule; C_1 and C_4 for seed yield/plant and C_3 and C_5 for oil content. Additive gene action for seed yield/plant was reported by Devasena *et al.* (2001).

While, the dominance variance was positive in C_2, C_3 and C_4 for days to maturity and 100 seed weight; C_4 for plant height; C_1, C_2 and C_4 for number of branches/plant; C_1 and C_2 for number of capsules/plant; C_4 and C_5 for capsule length; C_1 and C_5 for number of seeds/capsule and C_2, C_3 and C_5 for seed yield/plant. Dominance gene action was reported by Senthil Kumar *et al.* (2004) for seed yield/plant, Godawat and Gupta (1985) and Ramesh *et al.* (2000) for days to first flowering. The covariance of additive x dominance was positive C_1, and C_4 for days to maturity, plant height, number of branches/plant; C_2, C_3 and C_5 for capsule length, C_3 and C_5 for number of seeds/capsule and C_1 and C_2 for 100 seed weight; only in C_3 for seed yield/plant and C_2 and C_5 for oil content. These indicate the presence of more of dominant alleles in the parents, in the respective crosses for the respective traits.

In the present study, the degree of dominance was greater than unity in TMV 4 x KS99153 for days to first flowering, seeds/capsule and 100-seed weight, TMV 4 x KS 990812 for number of capsules/plant and TMV 4 x KS 990813 for 100 seed weight showed over dominance for the respective traits. Hence, it is suggested for adoption of heterosis breeding for these crosses in sesame. The plant height, number of branches/plant and seed yield was largely controlled by both additive and non-additive genetic variance. The pedigree or recombination breeding followed by selection in later generations would improve these characters. The capsules/plant and capsule length were controlled by additive genetic variance, simple selection or simple recurrent selection would be more effective in these crosses. The environmental variance for capsules/plant, capsule length, number of seeds/capsule and 100-seed weight revealed that environment plays an important role in the expression of these traits.

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Effect of sources and levels of sulphur on seed yield, oil content and economics of sesame, *Sesamum indicum* L. in Kymore plateau zone of Madhya Pradesh (India)

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Abstract

Field experiments were conducted on sesame (*Sesamum indicum* L.) cv. TKG-21 in clay loam soils of Jabalpur during *kharif* season of 2002 and 2004. Ten treatments consisting of three sources of sulphur *viz.*, single super phosphate (SSP), elemental sulphur (ES) and gypsum (GY) and three levels of sulphur *viz.*, 15, 30 and 45 kg/ha and one control (no sulphur application) were tested in randomised block design with three replications. The results revealed that application of S through different sources significantly increased the seed and oil yields. Among three sources, ES proved to be superior than other two sources at all levels of S application. Every incremental dose of S application correspondingly increased the seed and oil yield up to 45 kg S/ha, with all sources, except with application of S beyond 30 kg S/ha was not promising when it was applied through GY. Application of 15 kg S/ha through ES fetched the maximum net monetary returns (Rs. 11427/ha) with the B:C ratio of 2.47.

Key words: Sesame, sources, sulphur levels, oil content

Introduction

Sesame (*Sesamum indicum* L.) is an important rainy season oilseed crop of Madhya Pradesh. It is grown in about 1.5 lakh ha with the average productivity of 319 kg/ha. It is mostly grown in marginal and sub-marginal lands under rainfed conditions with little or no use of fertilizers. It is considered as a high value crop of low input use. The role of sulphur on yield and quality improvement of sesame is well established, as sulphur is the key constituent of oilseed and directly involved in the formation of fatty acids in oil compounds. Continuous cropping of sesame with the use of sulphur-free fertilizers viz. diammonium phosphate and urea under intensive crop sequences and removal of sulphur from soils is causing the wide spread deficiency of sulphur in sesame growing areas of the state resulting in declining productivity. Sharma and Kakate (1993) reported that seed yield of sesame increased from 25 to 30% with the application of sulphur. Sulphur application with an efficient source can improve the sesame yield. The present investigation was undertaken to evaluate the efficiency of sulphur and determine the optimum sulphur requirement in sesame for different parts of the Madhya Pradesh state under rainfed conditions.

Materials and methods

Field experiments were conducted at the research farm, JNKVV, Jabalpur during *kharif* season of 2002 and 2004. The soil of the experimental field was clay loam in texture, neutral in reaction (pH) and low in organic carbon (0.39%), available N (220 kg/ha), available P_2O_5 (7.85 kg/ha) available sulphur (6.8 kg/ha) and high in available K_2C (345 kg/ha). The rainfall received was 1218 and 1165 mm during the crop season in the two experimental years. Sesame cv TKG-21 was sown with 5 kg seeds/ha in rows 30 cm apart on July 27 and 5 during the year 2002 and 2004, respectively. The intra row spacing of 10 cm was maintained by thinning. Ten treatments consisted of three levels of sulphur (15, 30 and 45 kg/ha), three sources of S (single super phosphate, elemental sulphur and gypsum) and one absolute control (no sulphur application) which were tested in randomised block design with three replications (Table 1). Gypsum (GY) and single super phosphate (SSP) wee applied at the time of sowing, whereas, elemental sulphur (ES) was applied 15 days before sowing. The recommended dose of 60 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha was given through urea, diammonium phosphate and muriate of potash, respectively. The quantity of N and P was adjusted through these fertilizers by considering the quantity of P applied through single super phosphate as per treatments. The oil content in the seeds was recorded and the oil yields were computed. Data on seed yield were recorded in the respective years and economics of the treatments was worked out on the basis of the pooled mean for seed yield over the years.

Results and discussion

The seed yield was almost more than double during first year of experimentation under all treatments than the second year mainly due to variation in distribution of rainfall (Table 1). Though the rainfall was higher during first year, the heavy rainfall at early growth stage of crop in second year resulted in low plant population and poor growth of plants and ultimately gave lower seed yield. All the treated plots receiving S-application through different sources at varying rates significantly produced higher seed yield than control (no sulphur application) in both years. Every incremental dose of S as 15, 30 and 45 kg/ha through SSP and ES correspondingly increased the seed yield in both years, but variations between different S rates were not significant when it was applied through ES, whereas application of S through gypsum significantly increased the seed yield upto 30 kg S/ha and then drastically declined the yield with further increase in S at 45 kg/ha during first year, but seed yield significantly increased upto 45 kg S/ha during the second year. Among different sources of S, ES led to register significantly higher seed yield than SSP and gypsum with the same level of S-application. These results are in close conformity with the findings of Nagavani *et al.* (2001) and Duhoon *et al.* (2005). Oil content in seeds did not differ significantly due to different rates of S application through various sources during first year, but application of 15 kg and 30 kg S/ha through all the three sources significantly had higher oil content over control. Consequently all S treated plots significantly produced higher oil yield than control. Unlike seed yield, oil yield also showed increasing trend with increasing rates of S application upto 45 kg S/ha, but it reduced beyond 30 kg S/ha when gypsum was the source of S. The oil yield was maximum with application of S through ES at all levels than the other two sources.

Net monetary returns (NMR) and profitability (B:C ratio) of application of different levels of sulphur was found profitable over control. Application of 15 kg S/ha through ES fetched maximum NMR of Rs. 11427/ha closely followed by 45 kg S/ha through SSP (Rs. 11336/ha), 30 kg S/ha through ES (Rs. 11263/ha) and 30 kg S/ha through gypsum (Rs. 11191/ha). The NMR was minimum (Rs. 7011/ha) with control, while remaining treated plots fetched the NMR above to Rs. 10000/ha except with 15 kg S/ha through SSP (Rs. 8626/ha). B:C ratio was the lowest (2.08) in control which increased in S treatments from 2.16 to 2.56. The highest B:C ratio (2.56) was recorded with 30 kg S/ha through gypsum. Similar results in sesame have been reported by Nageshwar Lal *et al.* (1995), Sarawagi *et al.* (1995) and Duhoon *et al.* (2005).

Table 1 Effect of different levels and sources of sulphur on seed yield, oil yield and economics of sesame at Jabalpur

Treatment	Seed yield (kg/ha)			Oil (%)			Oil yield (kg/ha)			Economics	
	2002	2004	Mean	2002	2004	Mean	2002	2004	Mean	NMR*	B:C ratio
T_1 15 kg S/ha through SSP	1094	507	801	54.4	52.3	53.35	595	265	430	8626	2.16
T_2 30 kg S/ha through SSP	1285	521	903	55.8	52.3	54.05	717	272	495	10321	2.33
T_3 45 kg S/ha through SSP	1372	570	971	56.2	51.2	53.70	771	292	532	11336	2.40
T_4 15 kg S/ha through ES	1302	616	959	55.9	52.0	53.95	728	320	524	11427	2.47
T_5 30 kg S/ha through ES	1349	623	986	56.5	52.8	54.65	762	329	546	11263	2.33
T_6 45 kg S/ha through ES	1361	638	1000	55.8	52.6	54.20	759	336	548	10839	2.18
T_7 15 kg S/ha through GY	1233	498	866	55.7	52.5	54.10	687	261	474	10221	2.43
T_8 30 kg S/ha through GY	1302	532	917	55.0	52.0	53.50	716	277	496	11191	2.56
T_9 45 kg S/ha through GY	1198	582	890	54.9	51.3	53.10	658	299	478	10601	2.47
T_{10} Control (No sulphur)	955	400	678	55.8	51.0	53.45	533	204	368	7011	2.08
SEm±	27	7	-	0.65	0.24	-	-	-	-	-	-
CD (P=0.05)	84	22	-	NS	0.71	-	-	-	-	-	-

SSP = Single super phosphate; ES = Elemental sulphur; GY = Gypsum; NMR = Net monetary returns; * = Pooled mean basis for 2002 and 2004

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Evaluation of different integrated nutrient management options on growtl and yield of castor, *Ricinus communis* L.

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Abstract

A field experiment was conducted to study the effect of integrated nutrient management practices on the growth and yield of castor. Maximum growth in terms of plant height and drymatter production was observed with 75% recommended dose of nitrogen (RDN) + 25% N through poultry manure. Substitution of 25% RDN with poultry manure also resulted in longer primary and secondary spikes; more number of primary, secondary and tertiary spikes/plant and more number of capsules/spike. Integrated use of inorganic fertilizers with organic manures recorded seed yield similar to that of 100% RDN. Though, seed oil content did not vary significantly due to INM practices, oil yield was highest with application of 75% RDN + 25% N through poultry manure.

Key words: Castor, integrated nutrient management, growth, yield

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop fetching sizeable amount of foreign exchange to the country. It is the second most important oilseed crop of Andhra Pradesh next to groundnut. In Andhra Pradesh, castor occupies an estimated area of 249 thousand ha with a production of 114 thousand tonnes and a productivity of 456 kg/ha. It is grown under rainfed conditions in Andhra Pradesh. The poor agro-ecological resources in traditional castor growing areas of Andhra Pradesh - Telangana region characterized by shallow sandy loam soils, undulating topography, low soil fertility, low and uneven rainfall distribution had made its cultivation less remunerative during *kharif*. Improved cultivars, biological pest control, efficient management of land and water resources and integrated nutrient management are some of the means to achieve increased productivity. Among them, nutrient management must be sound for achieving production target on sustainable basis. Although use of chemical fertilizers is the fastest way of counteracting the pace of nutrient depletion, the ever rising energy cost and limited input availability coupled with many other factors deter farmers from using these inputs in balanced proportions and in recommended quantities. From technical, economical, logical and environmental considerations, the best option is t practise integrated nutrient management. Keeping this i view, the present study was conducted to evaluat integrated nutrient management (INM) options fc maximising the productivity of castor in souther Telangana zone of Andhra Pradesh.

Materials and methods

A field experiment was conducted at College Farr College of Agriculture, Rajendranagar, Hyderabad durin *kharif*, 2005. The soil of the experimental field was sand clay loam in texture, slightly alkaline (pH 7.4) with mediur organic carbon (0.5%), low available nitrogen (172. kg/ha) and phosphorus (22.6 kg/ha) and high potassiur (235.0 kg/ha) contents. Treatments were laid out i randomised block design with three replications havin plot size 6 m x 4.5 m. The treatments consisted of eigh nutrient management practices *viz.*, control (no fertilizers (T_1), 100% recommended dose of nitrogen (RDN) (T_2) 75% RDN + 25% N through FYM (T_3), 50% RDN + 50% N through FYM (T_4), 75% RDN + 25% N through poultr manure (T_5), 50% RDN + 50% N through poultry manur (T_6), 75% RDN + 25% N through castor cake (T_7) and 50% RDN + 50% N through castor cake (T_8). Castor seed were hand dibbled at a depth of 4-5 cm by adopting spacing of 60 cm x 45 cm. PCS-4 (Kranthi) cultivar wa used in the study. The recommended dose of fertilizer @ 60 N + 40 P_2O_5 + 30 K_2O kg/ha was applied in 100% RDN treatment. Entire dose of P and K and 1/3 of N wer applied basally and the remaining 2/3 N was applied in tw equal split doses at primary and secondary spike initiatio stages. In case of INM treatments, NPK content of organi manures were initially analysed and quantified to suit th scheduled quantity of N substitution as per the treatmer and incorporated in the soil at the time of final ploughing Nitrogen, phosphorus and potassium in chemical fertilize treatments were applied in the form of urea, single supe phosphate and muriate of potash, respectively.

Results and discussion

Growth characters of castor *viz.*, plant height an drymatter production did not vary significantly at earl stages (30 DAS) with INM practices due to non competitiveness for resources like moisture, light an nutrients owing to its slow initial growth rate.

The crop growth in terms of plant height increased progressively upto 90 days after sowing and thereafter, the rate of increase was meager (Table 1). Maximum plant height during the entire crop growth period was observed with 75% RDN + 25% N through poultry manure (T_5). Better performance of this treatment with respect to plant height might be due to lesser C:N ratio of poultry manure which resulted in mineralisation and increased availability of nitrogen to the plant throughout the crop growth period. Owing to highest plant height, drymatter production of castor was also maximum with 75% RDN + 25% N through poultry manure (T_5) treatment at all the crop growth stages which proved superior to all other treatments except with 75% RDN + 25% N through castor cake (T_7) (Table 1). These results are in conformity with the findings of Babulkar *et al.* (2000) in soybean and Talashilkar *et al.* (1997) in groundnut.

Observations on length of primary and secondary spikes (Table 2) revealed that significantly longer spikes were obtained with 75% RDN + 25% N through poultry manure (T_5) compared to other treatments (Table 2). Better growth of the plant coupled with adequate availability of nutrients from poultry manure might have resulted in the production of lengthy spikes as compared to other sources of nutrients. However, tertiary spike length did not differ significantly due to different INM practices, but based on mean data it was comparatively greater with 75% RDN + 25% N through poultry manure (T_5). These results are in accordance with the findings of Rao and Shaktawat (2002) in groundnut.

The number of spikes/plant and capsules/spike is an index of final yield as they are the significant contributory factors for seed yield in castor (Ramji Bind and Patil, 1997). In the study, the total number of spikes/plant recorded by 75% RDN + 25% N through poultry manure (T_5) was significantly higher compared to other treatments. Integration of inorganic nitrogen fertilizer with organic nitrogen source (poultry manure) has resulted in more number of spikes/plant compared to control (no fertilizer) (T_1) and 100% RDN (T_2) (Table 2).

The number of capsules/primary spike was significantly greater with 75% RDN + 25% N through poultry manure (T_5) as compared to other treatments (Table 2). Combination of two different sources of nitrogen (organic and inorganic) might be responsible for continuous and prolonged accumulation of photosynthates which in turn resulted in production of more number of filled capsules/spike. Similar results were observed with the application of poultry manure in groundnut (Rao and Shaktawat, 2002).

Secondary spikes contributed more to final seed yield as compared to that from primary spikes because the seed yield from primary spikes was less due to the incidence of grey rot disease.

Table 1 Plant height and drymatter production of castor as influenced by INM practices at various stages of crop growth

Treatment	Plant height (cm)					Drymatter production (kg/ha)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1 : Control (No fertilizer)	17.1	30.6	71.5	75.8	81.0	30.0	312	920	1530	2451
T_2 : 100% RDN (60-40-30 N-P_2O_5-K_2O kg/ha)	22.3	55.6	91.2	99.0	108.5	34.1	396	1362	1842	3207
T_3 : 75% RDN + 25% N through FYM	18.5	42.6	80.7	82.7	87.8	30.5	360	1160	1750	3160
T_4 : 50% RDN + 50% N through FYM	18.3	42.2	73.3	80.5	87.2	31.9	346	1080	1620	3042
T_5 : 75% RDN + 25% N through poultry manure	24.3	65.0	102.2	112.0	118.8	32.8	422	1490	1920	3275
T_6 : 50% RDN + 50% N through poultry manure	22.6	50.4	87.8	96.0	102.6	36.6	375	1208	1811	3172
T_7 : 75% RDN + 25% N through castor cake	22.5	56.9	91.4	106.5	111.0	31.5	411	1452	1883	3233
T_8 : 50% RDN + 50% N through castor cake	19.5	45.0	82.8	88.4	90.6	35.2	356	1140	1722	3075
SEm±	2.5	3.09	9.2	5.5	7.2	2.8	9.9	13.8	22.4	140.8
CD (P=0.05)	NS	9.4	27.9	16.7	21.0	NS	30.2	42.8	67.9	427.2

NS = Non-significant

Seed yield contribution from primary spikes (250 kg/ha), secondary spikes (285 kg/ha) and tertiary spikes (178 kg/ha) to the total seed yield (713 kg/ha) revealed that seed yield recorded by 75% RDN + 25% N through poultry manure (T_5) was found higher and was comparable with 100% RDN (T_2), 75% RDN + 25% N through FYM (T_3), 50% RDN + 50% N through FYM (T_4), 50% RDN + 50% N through poultry manure (T_6), 75% RDN + 25% N through castor cake (T_7) and 50% RDN + 50% N through castor cake (T_8) but significantly superior to control (T_1) (Table 3).

The significant increase in seed yield under INM treatments was due to beneficial effect of organic manures on growth and yield parameters through increased supply of nutrients with increased mineralisation and improvement of physico-chemical properties of the soil. These results are in accordance with the findings of Jagdev Singh and Singh (2000), Rao and Shaktawat (2002) and Reddy (2005). On the other hand, INM practices did not influence the oil content (Table 3) to a significant level but have shown favourable effect in the improvement of oil yield. Oil yield obtained with 75% RDN + 25% N through poultry manure (T_5) was significantly higher compared to rest of the treatments which is in agreement with the findings of Baby Akula and Bapi Reddy (1998).

Thus, integrated nutrient management practices were found as efficient as that of application of 100% RDN through inorganic fertilizers with improved growth and yield attributes. Among different organic sources, substitution of 25% RDN with poultry manure was found best with higher seed and oil productivity.

Table 2 Yield attributes of castor as influenced by INM practices at various stages of crop growth

Treatment	*Spike length (cm)*			*No. of spikes/plant*			*No. of capsules/spike*		
	Primary	Secondary	Tertiary	Secondary	Tertiary	Total*	Primary	Secondary	Tertiary
T_1 : Control (No fertilizer)	20.0	14.6	12.8	3	2	6	10	15	11
T_2 : *100% RDN (60-40-30 N-P_2O_5-K_2O* kg/ha)	28.0	19.0	13.0	4	4	9	21	16	13
T_3 : 75% RDN + 25% N through FYM	25.4	16.5	13.1	4	4	10	17	15	12
T_4 : 50% RDN + 50% N through FYM	24.0	16.0	13.0	4	3	9	15	15	12
T_5 : 75% RDN + 25% N through poultry manure	32.0	20.5	16.4	5	4	11	27	18	16
T_6 : 50% RDN + 50% N through poultry manure	26.5	17.7	13.6	4	4	9	20	16	13
T_7 : 75% RDN + 25% N *through castor cake*	30.2	19.6	15.0	5	4	10	23	17	14
T_8 : 50% RDN + 50% N through castor cake	25.5	17.0	13.4	4	4	10	13	15	12
SEm±	1.7	0.9	1.59	0.1	0.1	0.2	1.9	0.99	1.65
CD (P=0.05)	5.4	2.9	NS	0.4	NS	0.5	5.7	NS	NS

* One primary spike was added to the total secondary and tertiary spikes

Table 3 Seed yield, oil content and oil yield of castor as influenced by INM practices

Treatment	Seed yield (kg/ha)				Oil content (%)	Oil yield (kg/ha)
	Primary	Secondary	Tertiary	Total		
T_1 : Control (No fertilizer)	128	146	91	365	47.7	174
T_2 : 100% RDN (60-40-30 N-P_2O_5-K_2O kg/ha)	232	264	166	662	45.6	302
T_3 : 75% RDN + 25% N through FYM	226	258	161	644	46.4	299
T_4 : 50% RDN + 50% N through FYM	210	240	150	600	45.2	271
T_5 : 75% RDN + 25% N through poultry manure	250	285	178	713	47.3	337
T_6 : 50% RDN + 50% N through poultry manure	222	252	159	633	47.4	300
T_7 : 75% RDN + 25% N through castor cake	243	277	174	694	46.3	321
T_8 : 50% RDN + 50% N through castor cake	224	255	160	639	46.4	296
SEm±	18	15	11	39	1.3	4.0
CD (P=0.05)	55	46	43	118	NS	10.0

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Impact of WTO on oilseeds scenario in Andhra Pradesh

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Abstract

The present study was an attempt to assess the impact of WTO on area, production and productivity of oilseeds in Andhra Pradesh by estimating the patterns of growth and magnitude of instability, assessing the explanatory variables' affects and forming clusters of districts based on different criterion. The time series data for the period 1985-86 to 1994-95 and 1998-99 to 2007-08 on area, production and productivity were collected from various publications of the Bureau of Economics and Statistics, Government of Andhra Pradesh. Hierarchical and K-Means Clustering, Compound growth rate, Coppock's Instability Index, Decomposition of change in average production were employed for achieving the objectives.

The results revealed that growth performance of oilseeds production was higher during pre-WTO period than post-WTO period. But it was accompanied by high degree of instability. Decomposition analysis revealed that area effect was higher than the productivity effect on the production differential in Coastal Andhra and Telangana regions, where as, vice versa was noticed in Rayalaseema. So, growth in production should mainly come from area attributing factors like assured supply of farm inputs and provision of remunerative prices etc., in Coastal Andhra and Telangana regions, where as, in Rayalaseema it should be through yield attributing factors like input use efficiency and technology.

Key words: Oilseeds, clustering, growth, instability, decomposition analysis, Andhra Pradesh, Coastal Andhra, Rayalaseema and Telangana

Introduction

India is the one of the largest producer, consumer and importer of oilseeds in the world. In India, during the year 2007-08 (estimated), oilseeds were grown on 26.54 million ha with a production of 28.83 million tonnes and productivity of 1086 kg/ha. The nine major oilseeds grown in India are groundnut, castor, niger, sesamum, rapeseed and mustard, linseed, safflower, sunflower and soybean. Andhra Pradesh ranks fifth in oilseeds production with 2.24 (8.45%) million ha of area, 1.36 (5.6%) million tonnes of production and 609 kg/ha productivity during 2006-07. Pal Suresh and Sirohi (1989) has stated that in post-green revolution period (1967-68 to 1983-84) not only oilseed's yield was stagnant in most states but average yield decreased in some crops including state of Andhra Pradesh. Further, increase in area was large enough to offset the stagnant yields. Studies by Hazell (1984) and Jayadevan (1991) revealed that the growth in crop production during the post-green revolution period has been accompanied with increased instability and yield fluctuation turned out to be the major source of production instability. With this background to find out causes for fluctuations along with growth in Andhra Pradesh during pre and post WTO periods, an attempt has been made in the present study with the following specific objectives:

1. To study growth rates in area, production and productivity.
2. To examine the extent of instability in production.
3. To assess the change in average production caused by exploratory variables
4. To Identify the productivity clusters
5. To identify the growth and instability clusters based on production.

Materials and methods

The study pertains to state as a whole, three geographical regions of Andhra Pradesh *viz.*, Coastal Andhra, Rayalaseema and Telangana and all districts i.e., 22 districts (Because data for Hyderabad district is negligible). Here, the oilseeds means summing up of nine major oilseeds *viz.*, groundnut, castor, rapeseed and mustard, sunflower, safflower, soybean, niger, castor and linseed. The time series data for the pre-WTO period (1985-86 to 1994-95) and post-WTO period (1998-99 to 2007-08) on area, production and productivity were collected from various publications of the Bureau of Economics and Statistics, Government of Andhra Pradesh. In the data, four years break was given between two periods to allow the WTO impact percolate down to effect penultimately on area and productivity and in turn

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effect ultimately on production. Analysis was conducted separately for each period.

Analytical tools: Apart from budgeting techniques following analytical techniques were employed to achieve the objectives.

Estimation of growth rates: Compound growth rates (CGR) were estimated by fitting an exponential function of the following form.

$Y = A.b^t$

Log Y = Log A + t. log b

Where,

Y = Area/production/productivity; A = Constant; b = (1+r); r = Compound growth rate; t = Time variable in years (1, 2, 3.....n)

The value of antilog of 'b' was estimated by using LOGEST function in MS-Exel: Then, the per cent compound growth rate is calculated as below:

CGR (%) = [LOGEST (Y_1 : Y_{10}) - 1] x 100

Estimation of extent of instability: For the calculation of extent of instability, Coppock's Instability Index (CII) was employed. It is a close approximation of the average year-to-year percentage variation adjusted for trend. In algebraic form:

CII = [Antilog √log V - 1] x 100

$$\text{Log } V = \frac{[\text{Log } (X_{t+1}/X_t) - m]^2}{N-1}$$

Where,

Xt = Area/production/productivity in the year 't'; N = Number of years; Log V = Logarithmic variance; m = Arithmetic mean of difference between the logs of X_{t+1}, etc.

Decomposition of change in average production: Change in average production between the periods arises from changes in mean area and mean yield (productivity), interaction between changes in mean yield and mean area and change in yield-area covariance (Hazell, 1984).

The change in average production ΔE (P) between the periods can be obtained as follows:

$$\Delta E(P) = \bar{A}_1.\Delta Y + \bar{Y}_1.\Delta A + \Delta\bar{A}.\Delta\bar{Y} + \Delta \text{Cov}(A,Y)$$

Where,

$\bar{A}_1.\Delta Y, \bar{Y}_1.\Delta A, \Delta A.\Delta Y$ and $\Delta \text{Cov}(A,Y)$ are change in mean area, change in mean yield, changes in mean area and mean yield and changes in area and yield covariance respectively

Clustering: Cluster analysis is a multivariate procedure ideally suited to segmentation application. Clustering is the technique, which groups the objects of interest based on the proximities of the concerned character. Two-stage clustering technique was employed by using the Hierarchical and K-Means Clustering techniques (SPSS 15 trial version). Hierarchical Clustering gives the number of groups to be formed, where as, K-Means Clustering will decide the membership in each cluster.

Based on productivity: Hierarchical cluster analysis given three clusters of districts based on yield (kg/ha). These clusters were named as low (< 750), medium (750-1000) and high (> 1000).

Based on growth vis-à-vis instability: Hierarchical cluster analysis classified the districts into three clusters *viz*., low (< 0%), medium (0.1-2.0%) and high (> 2.1%), based on the production growth (CGR), similarly into three clusters *viz*., low (< 10%), medium (10-20%) and high (>20%) based on production instability (CII). Then, these three clusters each in growth and instability were cross tabulated and resulted in nine clusters *viz*., L-L (Low-Low),L-M,L-H,M-L,M-M,M-H,H-L,H-M, and H-H (High-High) clusters, and presented in the form of 3 x 3 tables (Tables 6 and 7). Further, analysis was carried for the both periods.

Results and discussion

Growth rates: During the pre-WTO period, state as a whole, growth rate was negative in productivity (- 1.67%), where as, growth rate in area (4.26%) was high and production (2.52%) was moderate (Table 1). So, growth in area contributed more towards growth in production than by growth in productivity. Among the regions, ranges of growth rates in area varied between 1.40% (Coastal Andhra) and 5.89% (Rayalaseema), in production they were from 1.24% (Coastal Andhra) to 4.79% (Telangana) and in productivity varied between - 3.47% (Rayalaseema) and 1.71% (Telangana). Growth rate in area was highest in Rayalaseema, in production and productivity was in Telangana. Lowest growth rate in area and productivity were noticed in Coastal Andhra, in production was noticed in Rayalaseema. Growth in area contributed more towards growth in production in all regions. Among the districts, range of growth rates in area was between -15.31% (East Godavari) and 9.73% (Nizamabad), in production the lowest was - 15.02% (East Godavari) and the highest was 11.13% (Medak), in productivity growth rates varied from -5.63% (Kadapa) to 12.39% (Nalgonda). East Godavari recorded the lowest growth rate in area and production, whereas, highest growth rates in all variables were noticed in among the districts of Telangana. Out of 22 districts, three (all belong to Coastal Andhra) in area, four (three belong to Coastal Andhra) in productivity and 11 (five belong to Coastal Andhra) in production has showed negative growth rates. During the pre-WTO period, in all variables districts of Coastal Andhra performance is dismal.

During the post-WTO period, among the districts, highest growth rate in area (11.40%), and production (10.74%) was recorded in Nizamabad and in productivity (5.91%) was recorded in West Godavari. Lowest growth rates in area (- 8.13%), production (- 8.68%) and productivity (-8.62) were noticed respectively in Khammam, Visakhapatnam and Nellore districts. Lowest growth rates in production and productivity were observed among the districts of Coastal Andhra region, while highest in area and production was noticed in districts of Telangana. Further, 11, 11, 10 districts registered with negative growth rates in area, production and productivity respectively. Among the regions, growth rates in area varied between -0.94% (Coastal Andhra) and 1.36% (Rayalaseema), in production varied from -0.84% (Coastal Andhra) to 5.78% (Telangana), in productivity varied between -2.65% (Rayalaseema) and 5.14% (Telangana). Growth in area contributed more towards growth in production than growth in productivity in Coastal Andhra, whereas, *vice versa* was noticed in Rayalaseema and Telangana. Similarly, state as a whole, growth in area (0.88%) contributed more towards growth in production (0.40%) than by growth in productivity (- 0.51%).

Pal Suresh and Sirohi (1989) has stated that there was poor growth in oilseeds production during 1950-51 to 1983-84. In post green revolution period (1967-68 to 1983-84) not only yield was stagnant in most states but average yield decreased in some crops including state of Andhra Pradesh. Further, stated that, increase in area was large enough to offset the stagnant yields. Present study revealed that growth in area and production were declined during post-WTO period (1998-99 to 2007-08) in comparison with pre-WTO period (1985-86 to 1994-95), whereas, *vice versa* was observed in productivity. After starting technology mission in oilseeds in 1980's there was increase in growth, as noticed from present study 4.26 and 2.52%, respectively in area and production during the pre-WTO period. But this was not sustained in post-WTO period as it is evidenced in area (0.88%) and production (0.40%) had less growth rates. But, negative growth in productivity was declined in post-WTO period (-0.51%) than during pre-WTO period (-1.67%). It is good sign that on production, effect of productivity increased during post-WTO period. The downtrend during post-WTO period may be same as stated by Rama Rao and Raju (2005) import liberalization on oil, increasing cultivation of oil palm, lack of improved technologies to sustain the impetus presented by Technology mission on oilseeds, innovation of synthetic products which are substitute for oilseeds in other than dietary purposes, natural vagaries, etc.

Extent of Instability: Among the districts, during the pre-WTO period, the lowest in area (5.57%), production (13.12%) and productivity (8.62%) were recorded in Visakhapatnam. Highest instability in area (60.61%), production (67.38%) and productivity (66.07%) were noticed in East Godavari, Kadapa and Kadapa respectively (Table 2). Lowest in all variables were noticed in Visakhapatnam. During the post-WTO period, the lowest area (7.19%), production (16.13%) and productivity (8.09%) were observed in Mahaboobnagar, Ranga reddy and Vizianagaram respectively. Highest instability in are (69.69%), production (86.78%) and productivity (37.90%) were registered respectively in Nizamabad, Nizamabad and East Godavari. In 13 out of 22 districts, contribution of instability in productivity in relation to variability in area was more towards production fluctuations.

Among the regions, during the pre-WTO period, the lowest instability in area (5.05%), production (10.18%) and productivity (6.88%) were recorded in Coastal Andhra, while, highest instability in area (18.16%), production (21.47%) and productivity (19.07%) were recorded in Rayalaseema. Contribution towards production fluctuations was more by variability in productivity in Coastal Andhra and Rayalaseema, whereas *vice versa* was in Telangana. During the post-WTO period, the lowest instability in area (8.12%) was noticed in Rayalaseema, while, in production (25.58%) and productivity (10.35%) were recorded in Coastal Andhra. While, the highest in area (18.54%) was noticed in Coastal Andhra, where as, in production (30.90%) and productivity (22.27%) were in Telangana. Contribution towards production variability was more by area variability in Coastal Andhra and by instability in productivity in Rayalaseema and Telangana.

State as a whole, during the pre-WTO period, area variability (12.77%) had more influence on production fluctuations (15.05%) than by instability in productivity (10.97%). Whereas, during the post-WTO period, instability in productivity (13.31%) had more influence on production variability (22.70%) than by instability in area (9.25%). Inter period comparison revealed that instability in area, production and productivity during the period II was more than period I.

Kaushik (1993), in his study on growth and instability of oilseeds in India over the period 1968-69 to 1991-92, has stated that fluctuation in productivity was the main cause of fluctuations in production. But, results of present study revealed that, during the pre-WTO period (1985-86 to 1994-95) in Andhra Pradesh, fluctuations in area (12.77%) had higher effect on production fluctuations (15.05%) than fluctuations in productivity (10.97%). Where as, during post-WTO period (1998-99 to 2007-08), yield variability (13.31%) had higher effect on production instability (22.70%) than area instability (9.25%). Reasons behind high variability in total oilseeds may be same as stated by Rama Rao and Raju (2005) that majority of oilseed crops were grown under rainfed conditions, low farm input efficiency, higher spacio-temporal variability in yields by same variety of particular crop or different crops, etc.

Clustering based on productivity

From the tables 4 and 5 it is clear that in pre-WTO period, 32.74, 49.47 and 17.79% of state average production was in high, medium and low cluster groups, respectively. Whereas, in post-WTO period, a good amount (52.23%) was in low cluster group. That shows the definite decrease in the productivity levels of some districts over the time. In the districts where productivity was decreased the magnitude was low, whereas, in the districts where productivity increased the magnitude was high. This was reflected in average productivity level in post-WTO period (0.91 tonnes/ha) which is higher than pre-WTO period (0.85 tonnes/ha). During pre-WTO period, six, eight and eight districts were in high, medium and low cluster groups respectively. Further, during post-WTO period, five, seven and 10 districts were in high, medium and low cluster groups respectively. This shows the movements of the some districts from high to medium and low ranges from pre-WTO period to post-WTO period. That is to say that three districts moved from low group to medium group, while, one district moved from medium to high groups.

But, point of concern is that productivity levels of 12 districts were stagnant. Whereas, one district each slipped from high to medium and medium to low productivity cluster groups respectively, while four districts slipped from medium to low productivity clusters.

Clustering based on growth *vis-à-vis* instability: Production growth was 2.52 and 0.40% in pre and post WTO periods respectively for state as a whole (Table 1). Basic fact is that average oilseeds production base itself decreased from pre to post-WTO period by 25% in the state.

Looking in isolated manner (Table 6), first from growth rates angle, there was 54% of production base was in high category, followed by 42% in medium and 4% in low category. While, from instability angle, 53% of production base was in medium category followed by 47% in high category.

Then looking from both *viz.*, growth and instability, the most desirable combination is the district with high growth and low instability (Top-right corner group), where as, opposite (Bottom-left corner group) is most undesirable group. Table 6 shows that in pre-WTO period, there was 29% of states' production base was in H-H (High growth and high Instability) category, followed by 28% in M-M category and 25% in M-H category. But, point of concern is that nearly 18% of production base is in L-H and M-H categories put together.

During post-WTO period, 58% of state production was in low growth category, followed by 36% in high category and 6% in medium category (Table 7). In instability category, 79% of the state production was in high category, followed by 21% in medium category. In joint situation of growth and instability, 57% of production was in L-H (low growth and high instability) category, followed by 19% in H-H (High growth and high instability) category. It reveals that growth and instability are going together.

Looking through tables 6 and 7, reveals that except 5 districts *viz.*, Srikakulam and East Godavari (L-L group) and Nizamabad, Mahaboobnagar and Medak (H-H group), all the districts moved from one category to another category from pre to post-WTO period. Majority of the districts moved from high growth category to medium and towards low groups, in instability also reverse trend was observed indicating that growth and instability are going together.

Most undesirable movement is in the direction from top-right corner (H-L group) to down-left corner (L-H group) like Vizianagaram, Ananthapur and Khammam districts' movement from M-M group to L-H group. Further, Visakhapatnam, Nellore and Chittoor from H-M to L-H group. Other undesirable movements are from right to left horizontally like Kadapa (from M-H to L-H), Karimnagar (from H-H to L-H), etc., and movement from top to bottom vertically like Prakasam (from (M-H to H-H) etc. Concern about movement from top-left corner to bottom-right corner and opposite direction depends upon production base. That is, if production base is high generally then low instability at the cost of growth is desirable, whereas, at low production base high growth is desirable at the cost of fluctuations.

Decomposition of change in average production: Among the districts, in 16 districts change in mean area has more effect on average production differential than by other components of change (Table 3). The highest mean area effect was recorded in Mahaboobnagar (408.87%), while, highest change in mean yield (278.49%) was noticed in Ananthapur.

Among the regions, from pre-WTO period to post-WTO period change in mean yield was higher than other components of change in Rayalaseema (144.49%), where as, change in mean area was higher than other components of change in Coastal Andhra (86.09%) and Telangana (338.14%), to effect the production differential from pre-WTO period to post-WTO period.

State as a whole, effect of change in mean yield (75.56%) was higher than mean area (34.17), mean area and yield (- 5.17%) and area and yield covariance (- 4.56%). Thus, change in mean yield has higher destabilizing effect on average production differential between the pre and post-WTO periods. One thing to note that, only in one region (Rayalaseema) change in mean yield has higher destabilizing effect on average production differential which was reflected in state as a whole which reminds us that high production base in that region (61.5% of state production in Rayalaseema).

Table 1 Compound growth rates of area, production and productivity of oilseeds in Andhra Pradesh during pre and post-WTO periods

(Values in percentages)

District and Region	Pre-WTO period (1985-86 to 1994-95)			Post-WTO period (1998-99 to 2007-08)		
	Area	Production	Yield	Area	Production	Yield
Srikakulam	-0.60	-0.79	-0.20	-1.81	-0.71	1.12
Vizianagaram	3.32	1.12	-2.13	-4.82	-5.46	-0.62
Visakhapatnam	0.49	3.10	2.60	-7.45	-8.68	-1.38
East Godavari	-15.31	-15.02	0.34	-8.58	-8.64	-0.06
West Godavari	-10.35	-6.55	4.24	1.66	7.72	5.91
Krishna	5.55	5.47	-0.08	-7.93	-3.23	5.23
Guntur	4.46	1.29	-3.04	7.02	8.02	3.44
Prakasam	7.02	4.43	-2.42	4.11	6.97	3.68
Nellore	2.51	3.82	1.27	8.52	-1.82	-8.62
Coastal Andhra	1.40	1.24	-0.16	-0.94	-0.84	0.32
Kurnool	8.70	6.34	-2.17	1.70	3.51	1.74
Ananthapur	5.54	0.28	-4.98	2.15	-2.33	-4.51
Kadapa	7.09	1.06	-5.63	3.00	-2.19	-5.02
Chittoor	2.26	3.88	1.58	-3.46	-4.51	-1.09
Rayalaseema	5.89	2.22	-3.47	1.36	-1.28	-2.65
Ranga Reddy	0.31	-5.32	-5.61	-3.26	2.21	5.66
Nizamabad	9.73	10.72	0.90	11.40	10.74	-0.44
Medak	5.64	11.13	5.19	3.04	8.47	5.38
Mahaboobnagar	4.10	2.18	-1.85	0.83	4.28	3.37
Nalgonda	-1.43	10.78	12.39	-1.42	0.10	1.53
Warangal	4.99	10.34	5.10	-4.40	0.07	4.69
Khammam	2.37	0.46	-1.87	-8.13	-9.74	-1.56
Karimnagar	7.60	9.77	2.03	-6.02	-4.21	1.90
Adilabad	4.33	7.08	2.63	14.60	42.34	24.06
Telangana	3.03	4.79	1.71	0.57	5.78	5.14
Andhra Pradesh	4.26	2.52	-1.67	0.88	0.40	-0.51

Table 2 Coppock's instability indices (CII) of area, production and productivity of oilseeds in Andhra Pradesh during pre and post-WTO periods

(Values in percentages)

Districts and Regions	Pre WTO period (1985-86 to 1994-95)			Post WTO period (1998-99 to 2007-08)		
	Area	Production	Yield	Area	Production	Yield
Srikakulam	9.67	21.91	20.34	9.77	20.69	13.16
Vizianagaram	5.77	14.52	18.38	20.02	23.22	8.09
Visakhapatnam	5.57	13.12	8.62	26.70	31.90	8.65
East Godavari	60.61	63.19	8.64	40.05	65.31	37.90
West Godavari	35.08	29.94	13.26	24.02	31.01	27.84
Krishna	21.25	18.40	11.37	51.74	48.84	22.80
Guntur	25.25	27.28	12.05	31.71	41.19	19.19
Prakasam	20.69	18.33	10.52	44.03	47.74	23.57
Nellore	15.17	14.68	15.42	53.71	28.09	26.86
Coastal Andhra	5.05	10.18	6.88	18.54	21.58	10.35
Kurnool	23.71	24.89	14.84	8.06	17.38	12.80
Ananthapur	13.93	18.66	22.33	9.27	44.57	38.86
Kadapa	22.99	67.38	66.07	16.67	29.29	24.27
Chittoor	8.81	19.72	13.73	26.54	28.63	7.27
Rayalaseema	18.16	21.47	19.07	8.12	25.54	18.92
Ranga Reddy	7.19	35.70	36.43	18.45	16.13	28.00
Nizamabad	39.37	46.32	18.66	69.69	86.78	24.32
Medak	19.64	44.18	26.60	30.21	45.66	30.14
Mahaboobnagar	19.77	28.81	25.21	7.19	20.46	14.63
Nalgonda	9.76	13.67	16.18	13.52	24.04	16.09
Warangal	15.42	28.24	23.27	20.92	17.01	20.27
Khammam	13.91	15.67	10.09	42.62	62.09	23.80
Karimnagar	23.57	35.72	12.25	41.18	30.14	22.58
Adilabad	21.77	47.94	32.12	48.78	56.57	13.78
Telangana	11.04	13.77	9.63	13.04	30.90	22.27
Andhra Pradesh	12.77	15.05	10.97	9.25	22.70	13.31

Table 3 Components of change in average production in oilseeds between pre and post WTO periods

(Values in percentages)

District and Region	Sources of change			
	Change in mean yield	Change in mean area	Changes in mean area and mean yield	Changes in area and yield covariance
Srikakulam	30.12	78.36	-6.64	-1.84
Vizianagaram	57.07	56.93	-15.98	-0.02
Visakhapatnam	2.44	98.65	-0.98	-0.11
East Godavari	-0.42	102.15	0.35	-2.08
West Godavari	-166.91	180.38	94.55	-8.02
Krishna	-52.76	117.20	33.75	1.84
Guntur	19.04	90.26	-8.39	-0.91
Prakasam	33.24	76.82	-11.69	1.63
Nellore	21.56	54.62	-3.81	27.63
Coastal Andhra	19.87	86.09	-7.36	1.4
Kurnool	-29.65	98.11	-1.83	33.37
Ananthapur	278.49	-216.87	67.11	-28.73
Kadapa	106.47	-6.93	3.16	-2.70
Chittoor	46.15	64.34	-10.29	-0.20
Rayalaseema	144.49	47.17	12.25	-9.57
Rangareddy	-8.81	101.58	3.35	3.88
Nizamabad	15.08	72.68	11.01	1.23
Medak	78.61	17.471	7.8	-3.82
Mahaboobnagar	1.03	408.87	-0.02	-309.88
Nalgonda	1.18	101.87	-0.42	-2.63
Warangal	-237.92	233.08	85.24	19.60
Khammam	41.85	82.89	-22.69	-2.05
Karimnagar	-19.72	102.37	9.61	7.74
Adilabad	38.01	11.96	25.02	25.01
Telangana	-281.09	338.14	50.75	-7.80
Andhra Pradesh	75.56	34.17	-5.17	-4.56

Table 4 Productivity (tonnes/ha) clusters of different districts in pre-WTO period (1985-86 to 1994-95)

Cluster-I (High)		Cluster-II (Medium)		Cluster-III (Low)	
Name	Yield	Name	Yield	Name	Yield
Nellore	1.55	Khammam	0.93	Warangal	0.68
Kadapa	1.20	Nizamabad	0.92	E. Godavari	0.63
Krishna	1.13	Srikakulam	0.92	Visakhapatnam	0.61
Chittoor	1.12	Guntur	0.88	Medak	0.55
W. Godavari	1.02	Vizianagaram	0.87	Mahaboobnagar	0.52
Karimnagar	1.01	Prakasam	0.82	Nalgonda	0.48
		Kurnool	0.78	Ranga reddy	0.46
		Ananthapur	0.75	Adilabad	0.26
Average	1.17		0.86		0.52
% to State productivity	138		101		61
Share in State production (%)	32.74		49.47		17.79

Note 1: State average productivity during pre-WTO period is 0.85 tonnes/ha
Note 2: State average production during pre-WTO period is 25, 02,719 tonnes

Table 5 Productivity (tonnes/ha) clusters of different districts in post-WTO period (1998-99 to 2007-08)

Cluster-I (High)		Cluster-II (Medium)		Cluster-III (Low)	
Name	Yield	Name	Yield	Name	Yield
W. Godavari	1.50	Chittoor	0.91	Prakasam	0.73
Krishna	1.42	Adilabad	0.87	Khammam	0.70
Nellore	1.38	Srikakulam	0.85	Vizianagaram	0.66
Nizamabad	1.08	Warangal	0.84	E. Godavari	0.62
Karimnagar	1.07	Guntur	0.82	Kadapa	0.60
		Kurnool	0.80	Ananthapur	0.58
		Medak	0.75	Visakhapatnam	0.57
				Ranga reddy	0.56
				Mahaboobnagar	0.56
				Nalgonda	0.45
Average	*1.29*		*0.83*		*0.6*
% to State productivity	142		91		66
Share in State production (%)	7.39		39.38		53.23

Note 1: State average productivity during post-WTO period is 0.91 tonnes/ha
Note 2: State average production during post-WTO period is 18, 78,212 tonnes

Table 6 Cross tabulated growth and instability clusters in pre-WTO period (1985-86 to 1994-95)

(Production in tonnes)

Growth cluster/Instability Cluster	Cluster-I (Low)		Cluster-II (Medium)		Cluster-III (High)		All groups' share in state production (%)
	District Name	A.P*	District Name	A.P*	District Name	A.P*	
Cluster-I (Low)	Nil		Nil		Nil		
Each groups' share in state production (%)		0		0		0	0
			Vizianagaram	90000	Visakhapatnam	42429	
			Ananthapur	567429	Prakasam	92286	
Cluster-II (Medium)	Nil		Khammam	42143	Nellore	67571	
					Chittoor	319571	
					Nalgonda	91286	
Each groups' share in state production (%)		0		28		25	53
	Srikakulam	52429	Guntur	36286	Krishna	43857	
	East Godavari	12714	Kadapa	302286	Kurnool	338000	
	West Godavari	13000			Nizamabad	19429	
Cluster-III (High)	Ranga reddy	19571			Mahaboobnagar	158571	
					Warangal	93000	
					Karimnagar	73143	
					Adilabad	10857	
Each groups' share in state production (%)		4		14		29	47
All groups' share in state production (%)		4		42		54	100

Note: State average production during pre-WTO period is 25, 02,719 tonnes
*AP = Average production in pre-WTO period for the respective districts

Table 7 Cross tabulated growth and instability clusters in post-WTO period (1998-99 to 2007-08)

(Production in tonnes)

Growth Clusters/Instability Cluster	Cluster-I (Low)		Cluster-II (Medium)		Cluster-III (High)		All groups' share in state production (%)
	Name	A.P*	Name	A.P*	Name	A.P*	
Cluster-I (Low)	Nil		Nil		Nil		
Each groups' share in state production (%)		0		0		0	0
Cluster-II (Medium)	Ranga reddy	14775	Warangal	66902	Kurnool	328708	
Each groups' share in state production (%)		1		3		17	21
	Srikakulam	38917	Nalgonda	56570	West Godavari	10444	
	Vizianagaram	49944			Guntur	16767	
	Visakhapatnam	23378			Prakasam	45805	
	East Godavari	3078			Nizamabad	34017	
	Krishna	18260			Medak	23363	
Cluster-III (High)	Nellore	42600			Mahaboobnagar	152338	
	Ananthapur	493600			Adilabad	69685	
	Kadapa	145674					
	Chittoor	195287					
	Khammam	14702					
	Karimnagar	33397					
Each groups' share in state production (%)		57		3		19	78.15
All groups' share in state production (%)		58		6		36	100

Note: State average production during post-WTO period is 18, 78,212 tonnes
*AP = Average production in post-WTO period for the respective districts

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Short Communication

Exploitation of heterosis breeding in Indian mustard, *Brassica juncea* (L.) Czern & Coss

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Abstract

Forty five F_1 crosses of Indian mustard [*Brassica juncea* (L.) Czern and Coss] in a diallel set involving ten parents (excluding reciprocals) was studied to investigate mid-parent, better parent and economic heterosis over check variety GM 2 for seed yield and its component traits. The analysis of variance for various characters revealed that the considerable genetic variation existed among the parents and hybrids for all the traits under study. Comparison of mean squares due to parents vs. hybrids indicated presence of overall heterosis for all the characters except days to 50% flowering, days to maturity and length of main branch. The standard heterosis for seed yield and its components traits revealed that the highest standard heterosis for seed yield was observed in RH 819 x SKM 9928 (111.75%) followed by GM 1 x GM 2 (102.48) and GM 1 x RH 819 (95.25%). Amongst these hybrids, the RH 819 x SKM 9928 was heterotic over GM 2 for various yield components, whereas, the hybrids GM 1 x GM 2 and GM 1 x RH 819 were also heterotic for primary branches/plant and oil content. It is to mention that at least one good parent with high *per se* performance involved in the hybrids has resulted in high heterotic effects.

Key words: Indian mustard, heterosis, heterobeltiosis, *Brassica juncea*

Indian mustard is one of the most important oilseed crops grown during *rabi* season. Heterosis breeding could be potential alternative for achieving quantum jumps in production and productivity. The magnitude of heterosis particularly for seed yield is of paramount importance and if the heterosis is feasible it can help to reach high yield levels and thereby higher output of oil in mustard.

The experimental material for the present investigation consist of 10 lines of Indian mustard *viz.*, TM 18, GM 1, GM 2, RH 819, RH 30, PCR 7, SKM 9585, SKM 9927, SKM 9928 and SAL 1 and hybrids generated by crossing the above lines in all possible combinations. The 10 parents and their 45 F_1s were raised in randomized block design with three replications at Main Castor and Mustard Research Station, Gujarat Agriculture University, Sardarkrushinagar during *rabi* 2002-03. Each genotype was sown is single row of 3 M length with spacing of 45 cm x 15 cm. All the management practices were followed as per recommendations to raise a normal crop. Observations were recorded on 10 characters for five competitive plants selected at random per plot. The mean values of each genotypes were subjected to calculate heterosis as per cent deviation from mid-parent, the better parent and the standard check variety, GM 2 for each character.

The analysis of variance revealed highly significant differences among the genotypes for all the characters. Further, partitioning of mean sum of square of genotype, *viz.*, parents and hybrids suggested significant differences among parents and hybrids for most of the characters. This indicated the existence of considerable amount of genetic variability in the experimental materials. The mean squares for parents vs. hybrids was found to be highly significant for all the characters except days to 50% flowering and maturity, length of main branch and number of secondary branches/plant, which implied that performance of hybrids was significantly different than that of the parents for most of the characters (Table 1).

Significant negative heterosis was recorded for days to 50% flowering, which is desirable for the development of early type. It was observed that crosses showing negative heterosis for 50% flowering did not always exhibit negative heterosis for days to maturity revealing complex nature of gene action. Fourteen hybrids expressed consistently significant and negative standard heterosis for plant height. The crosses SKM 9585 x SAL 1 (-17.20%), TM 18 x GM-1 (-14.43%) and TM 18 x SKM 9585 (-13.91%) were the best three hybrids for plant height. From this it was observed that cross involving TM 18 and SAL 1 as one of the parents showing dwarfness suggesting their use as a potential donor parents for the development of dwarf varieties. Significant heterosis was recorded for various yield contributing characters. The crosses showing highest heterosis with respect to each of these characters is presented in table 2.

For seed yield, 32 crosses depicted significant positive relative heterosis, 17 crosses exhibited significant positive heterobeltiosis, while, significant *positive standard* heterosis was exhibited by 32 crosses. A study of standard heterosis for seed yield and its component traits revealed that the hybrid RH 819 x SKM 9928 expressing the highest standard heterosis (111.75%) for seed yield/plant, also manifested high standard heterotic effects for yield contributing traits *viz.*, number of primary and secondary branches/plant, number of siliquae/plant and oil content. Similar trend was observed in other high standard heterotic hybrids *viz.*, GM 1 x GM 2 and GM 1 x RH 819. High association among these attributes as well as seed yield have been reported as in the case of combinational heterosis (Joshi and Patil, 2003). The standard heterosis for number of primary and secondary branches (83.62 and 64.69%, respectively) were very high. For 1000 seed weight and oil content heterosis in desired direction was moderately low. A standard heterosis for number of siliquae/plant was moderate (41.15%). The use of crosses exhibiting high heterosis of yield and its component characters in breeding programmes aimed at development of high yielding varieties is advocated. The superior F_1 hybrids are expected to produce transgressive segregants if additive genetic systems of the superior *parent and complimentary epistatic effect* of the F_1 act in the same direction to maximize intensity of the desirable yield attributes.

Table 1 Analysis of variance for parents and hybrids for yield and its component characters in Indian mustard

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height	Length of main branch	No. of primary branches/ plant	No. of secondary branches / plant	No. of siliquae/ plant	1000-seed weight	Oil content	Seed yield /plant
Replication	2	2.01	27.29**	17.41	98.39	0.13	43.15**	2958.18	0.25	8.39**	11.08*
Genotypes	54	23.53**	6.31**	632.09**	86.16**	0.70**	4.85**	3045.57**	1.41**	3.96**	22.15**
Parents	9	42.13**	15.29**	1063.94**	146.59**	2.01**	11.24**	4173.72**	2.60**	4.81**	32.48**
Hybrids	44	20.13**	4.52**	549.79	75.41**	0.43**	3.46**	2696.74*	1.11**	2.55**	18.69**
Parents vs. Hybrids	1	6.04	4.59	365.00**	15.19	1.01*	8.38	8242.65*	3.68**	58..29**	81.20**
Error	108	1.90	2.22	62.66	24.62	0.20	1.90	1660.50	0.27	1.10	3.21
SEm±		0.79	0.86	4.57	2.86	0.25	0.79	23.52	0.3	0.60	1.03
CD (P=0.05)		2.21	2.41	12.82	8.02	0.70	2.21	65.99	0.84	1.68	2.89

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

Table 2 Summary of highest heterotic cross combinations in *desired direction and range of* heterosis (%) with respect to each character in Indian mustard

Character	Best heterotic crosses and Range of Heterosis (%)		
	Over mid parent	Over better parent	Over check (GM 2)
Days to 50% flowering	RH 819 x SKM 9928 (-11.02 to 2.37)	RH 819 x SKM 9928 (-9.60 to 22.00)	TM 18 x GM-1 (-20.65 to 5.80)
Days to maturity	GM 2 x SKM 9585 (-1.80 to 2.37)	RH 30 x SKM 9927 -0.92 to 4.84	TM 18 x SAL 1 (-4.26 to 1.22)
Plant height	GM 1 x SKM 9928 (-13.11 to 11.01)	GM 1 x GM 2 (-8.51 to 27.48)	SKM 9585 x SAL 1 (-17.28 to 12.44)
Length of main branch	RH 819 x SKM 9928 (- 14.54 to 19.51)	RH 819 x SKM 9928 (-17.93 to 18.11)	GM 1 x SKM 9585 (-11.33 to 13.41)
Number of primary branches/plant	GM-1 x GM-2 (-19.21 to 42.22)	GM 1 x GM 2 (-27.38 to 36.17)	TH 819 x SKM 9928 (25.53 to 83.62)
Number of secondary branches/plant	GM 1 x GM 2 (-30.43 to 37.76)	RH 30 x PCR 7 (-36.72 to 14.72)	RH 819 x SKM 9928 (-0.96 to 64.09)
Number of siliquae/plant	GM 2 x PCR 7 (-27.23 to 22.80)	GM 1 x SAL 1 (-32.59 to 15.01)	TM 18 x SKM 9585 (-11.40 to 41.15)
1000 seed weight	GM 1 x SAL 1 (-2.11 to 31.54)	RH 819 x PCR 7 (-18.89 x 18.56)	RH 819 x PCR 7 (-23.07 to 27.01)
Oil content	PCR 7 x SAL 1 (-2.30 to 9.56)	*GM 2 x PCR 7* (- 5.33 to 8.51)	*GM 1 x RH 30* (-0.27 to 9.57)
Seed yield/plant	TM 18 x GM 2 (-28.34 to 89.59)	TM 18 x GM 2 (-39.47 to 57.19)	RH 819 x SKM 9928 (2.15 to 111.75)

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Short communication

Genetic determination of yield in rapeseed, *Brassica campestris* L. var. *Sarson*

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Abstract

Interrelationship analysis was carried out in 66 genotypes of rapeseed. Seed yield had highly significant positive association with days to 50% flowering, days to maturity, plant height, number of branches/plant, number of siliquae on main branch, number of siliquae/plant and harvest index, while, non-significant and negative correlation with seeds per siliqua and oil content. Path coefficient analysis revealed that component traits *viz.*, harvest index and number of siliquae on main branch had high and positive direct effect along with strong positive association with seed yield. Low to high positive indirect effect on seed yield via all other component traits except 1000 seed weight was observed, indicating that greater emphasis should be laid on selection for these traits to achieve improvement in yield level.

Keywords: *Brassica campestris,* rapeseed, correlation, path analysis

Rapeseed-mustard is an important winter season oilseed crop of India. To evaluate the relative influence of component characters on yield, the path coefficient analysis was followed which permits the separation of correlation coefficient into the measure of direct and indirect effects. In the present study, an attempt was made to analyse seed yield and its attributing characters of rapeseed by correlation and path coefficient analysis.

Sixty six genotypes of rapeseed were collected and planted in randomized block design replicated thrice during winter season of 2004-05 at Main Castor and Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar. The spacing between rows and plant to plant was kept 45 cm and 15 cm, respectively. Observations were recorded on ten randomly selected plants from each replication and data were recorded for days to 50% flowering, days to maturity, plant height (cm), length of main branch (cm), branches/plant, number of siliquae on main branch, siliquae/plant, seeds/siliqua, 1000 seed weight (g), oil content (%), harvest index (%) and seed yield/plant (g). The character association was estimated from variance and covariance components as given by Fisher (1954) and Al-Jibouri *et al.* (1958) and the direct and indirect effects of characters upon seed yield were measured by path analysis as per Dewey and Lu (1959).

The genotypic correlations were generally higher than the phenotypic correlations indicating the inherent association between various traits (Table 1). Seed yield showed highly significant positive association with days to 50% flowering, days to maturity, plant height, length of main branch, branches/plant, number of siliquae on main branch, siliquae/plant and harvest index. While, it was non-significant and negative association with seeds/siliqua and oil content at both genotypic and phenotypic levels.

Days to 50% flowering and maturity showed positive and highly significant association with plant height and siliquae/plant but highly significant and negative association with oil content and harvest index at both the levels. Plant height exhibited highly significant and positive correlation with number of branches/plant, length of main branch, number of siliquae on main branch, siliquae/plant and seed yield/plant. Present finding is in conformation with the results obtained by Singh and Singh (1995).

The number of branches/plant showed highly significant and positive correlation with plant height, length of main branch, number of siliquae on main branch and siliquae/plant. Number of siliquae/plant expressed significant and negative correlation with 1000 seed weight and oil content. The seeds/siliqua showed positive and non-significant correlation with oil content. The trait, 1000 seed weight expressed positive and highly significant correlation with oil content. Oil content also showed positive and highly significant correlation with harvest index at both the levels. Harvest index expressed positive and highly significant correlation with seed yield at both genotypic and phenotypic levels.

In the present investigation, the highest positive direct effect on seed yield was recorded for harvest index (0.487) followed by number of siliquae on main branch, plant height, siliquae/plant, seeds/siliqua and days to maturity (Table 2). Similar results have been reported by Singh and Mishra (2002) for number of siliquae/plant and seeds/siliqua and Kumar *et al.* (2004) for seeds/siliqua. The negative direct effect of branches/plant was high, while, days to 50% flowering was moderate and for length of main branch was low, such negative direct effects were also reported by Singh *et al.* (1990) for branches/plant and Singh and Singh (1995) for days to 50% flowering.

The number of siliquae on main branch possessed very high (0.586) correlation with seed yield/plant, which was due to its high positive direct effect (0.445) and high positive indirect effect via plant height. Plant height exhibited high correlation with seed yield, which was due to its high positive direct and indirect effects via number of siliquae on main branch. The high positive correlation for harvest index was exhibited with seed yield/plant, which was due to its very high (0.487) positive direct effect. In the study, the residual effect at genotypic level was 0.281, which suggested that there might be few more component traits responsible to influence the seed yield.

For the improvement of the seed yield, emphasis should be made on yield contributing traits, which are influencing it directly or indirectly. In the present study, path analysis revealed that for improving seed yield in rapeseed, weightage in selection should be given to more plant height, late flowering and maturity, more branches/plant, long main branch, more siliquae on main branch, more siliquae/plant, bold seed, high oil content and high harvest index.

Table 1 Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients among twelve characters in rapeseed

Character	Days to 50% flowering	Days to maturity	Plant height	Branches/ plant	Length of main branch	Number of siliquae on main branch	Siliquae/ plant	Seeds/ siliqua	1000 seed weight	Oil content	Harvest index	Seed yield/ plant
Days to 50% flowering	-	0.822**	0.709**	0.074	0.038	0.178*	0.222**	0.004	0.290**	-0.304**	-0.238**	0.292**
Days to maturity	0.806**	-	0.714**	0.136	0.038	0.331**	0.304**	-0.138*	0.136	-0.339**	-0.200**	0.395**
Plant height	0.700**	0.699**	-	0.354**	0.466**	0.573**	0.303**	-0.142**	0.143*	-0.360**	-0.236**	0.492**
Length of main branch	0.061	0.124	0.319**	-	0.266**	0.422**	0.283**	0.012	0.022	-0.222**	0.159*	0.194**
Branches/ plant	0.035	0.044	0.454**	0.232**	-	0.510**	0.133	-0.066	-0.044	-0.110	0.042	0.358**
No. of siliquae on main branch	0.166*	0.299**	0.526**	0.358**	0.458**	-	0.376**	-0.305**	-0.134	-0.340**	-0.024	0.586**
Siliquae/plant	0.217**	0.298**	0.299**	0.243**	0.129	0.336**	-	-0.109	-0.206**	-0.273**	0.199**	0.510**
Seeds/siliqua	0.023	-0.078	-0.103	0.015	-0.050	-0.190**	-0.162*	-	0.010	0.063	0.055	-0.027
1000 seed weight	0.230**	0.118	0.112	0.025	-0.036	-0.102	-0.172*	-0.034	-	0.200**	0.096	0.054
Oil content	-0.256**	-0.275**	-0.294**	-0.171*	-0.091	-0.281**	-0.226**	0.031	0.253**	-	0.345**	-0.106
Harvest index	-0.223**	-0.184**	-0.220**	0.139*	0.039	-0.010	0.185**	-0.085	0.121	0.296**	-	0.393**
Seed yield/plant	0.279**	0.369**	0.470**	0.173*	0.333**	0.503**	0.486**	-0.063	0.042	-0.082	0.378**	-

* $P \leq 0.05$, ** $P \leq 0.01$

Table 2 Path coefficient analysis showing direct (bold) and indirect effects of eleven traits on seed yield in rapeseed

Characters	Days to 50% flowering	Days to maturity	Plant height	Branches/ plant	Length of main branch	No. of siliquae on main branch	Siliquae/ plant	Seeds/ siliqua	1000 seed weight	Oil content	Harvest index	Genotypic correlation on seed yield/plant
Days to 50% flowering	**-0.115**	0.129	0.252	-0.020	0.002	0.079	0.055	0.005	0.028	-0.003	-0.116	0.292**
Days to maturity	-0.095	**0.156**	0.254	-0.037	0.001	0.147	0.075	-0.017	0.013	-0.003	-0.098	0.395**
Plant height	-0.082	0.112	**0.355**	-0.097	-0.001	0.255	0.075	-0.020	0.014	-0.003	-0.115	0.492**
Length of main branch	-0.009	0.021	0.126	**-0.274**	0.001	0.188	0.070	-0.005	0.002	-0.002	0.077	0.194**
Branches/ plant	-0.004	0.006	0.166	-0.073	**-0.002**	0.227	0.033	-0.009	-0.004	-0.001	0.020	0.358**
No. of siliquae on main branch	-0.021	0.052	0.203	-0.116	-0.001	**0.445**	0.093	-0.042	-0.013	-0.003	-0.012	0.586**
Siliquae/plant	-0.026	0.048	0.108	-0.077	0.001	0.167	**0.247**	-0.031	-0.019	-0.003	0.097	0.510**
Seeds/siliqua	-0.003	-0.015	-0.040	0.008	0.001	-0.107	-0.044	**0.176**	-0.006	0.000	-0.039	-0.027
1000 seed weight	-0.034	0.021	0.051	-0.006	0.001	-0.060	-0.051	-0.011	**0.095**	0.002	0.047	0.054
Oil content	0.035	-0.053	-0.128	0.061	0.001	-0.151	-0.068	0.001	0.019	**0.010**	0.168	-0.106
Harvest index	0.027	-0.031	-0.084	-0.044	0.001	-0.011	0.049	-0.014	0.009	0.003	**0.487**	0.393**

Residual effect = 0.281, ** $P \leq 0.01$

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Short communication

Combining ability and heterosis in rapeseed, *Brassica campestris* L. var. *Toria*

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Abstract

Combining ability and heterosis were studied in relation to mean performance of all possible cross combination in a 5 x 5 diallel involving diverse genotypes of rapeseed. Barring 1000 seed weight, most of the crosses exhibited significantly high *sca* and heterosis over both mid-parent and better parent for seed yield and component traits indicating predominance of non-additive gene action. Hence, a wider scope of heterosis breeding and recurrent selection has been suggested. M 27 x OCPT 4 was the best specific combiner for number of primary branches/plant, siliquae/plant, harvest index and seed yield/plant.

Keywords: Rapeseed, heterosis, combining ability

Brassica campestris var. *toria* is one of the most important oilseed crops in oilseed economy of our country. It is often preferred in cereal-oilseed cropping sequence due to its short maturity duration and high net return. Average productivity of rapeseed-mustard in India stands at 1190kg during 2008-09 (Anonymous 2009), whereas it is more than double in Korean Republic, Japan, and neighbouring China. Recombination breeding can bring about desirable combination of genes of suitable parents leading to spectacular improvement in production and productivity. Available literature reveal commercially exploitable magnitude of heterosis for seed yield in rapeseed-mustard. But, no significant breakthrough has yet been achieved for seed yield *per se* possibly due to arbitrary choice of parents and inadequate information about nature of gene action in the materials used. An experiment, therefore, was undertaken to study the magnitude of heterosis and combining ability and genetic basis of character expression in various cross combinations which will be useful for further improvement over the available genotypes.

Table 1 Mean performance and general combining ability effects of five parents

Parent	Days to 50% flowering	Plant height (cm)	Number of primary branches	Siliquae /plant	1000 seed weight (g)	Yield/plant (g)	Harvest index (%)
M 27	40	73	3.9	46.3	1.9	0.408	21.4
	(0.086)	(0.543)	(0.306**)	(6.343**)	(-0.120**)	(-0.015)	(-1.160)
TS 29	37	53	3.1	35.0	2.5	0.300	30.0
	(-1.486**)	(-6.886**)	(-0.080)	(-0.957)	(0.080**)	(-0.038**)	(2.140**)
OCPT 4	43	77	3.4	35.3	2.0	0.407	22.5
	(1.800**)	(5.257**)	(0.148)	(-2.257)	(-0.060**)	(0.020)	(-0.460)
PT303	39	75	3.0	39.0	2.3	0.500	21.7
	(-0.628)	(3.114*)	(-0.080)	(-0.171)	(0.137**)	(0.033*)	(-0.546)
BT 1	49	72	3.3	42.4	2.4	0.417	19.7
	(0.228)	(-2.028)	(-0.294**)	(-2.957)	(-0.034)	(0.0004)	(0.026)
SE (gi)	356	1.325	0.083	1.654	0.018	0.013	0.764
SE (gi-gj)	0.565	2.096	0.131	2.620	0.123	0.021	1.210
CD (gi-gj) at 5%	1.157	4.292	0.268	5.366	0.252	0.043	2.478
CD (gi-gj) at 1%	1.561	5.791	0.362	7.239	0.340	0.058	3.343

Figures within the parenthesis indicate *gca* effects

Table 2 Mean performance, heterosis and *sca* effects of all possible crosses of five parents

Cross		Days to 50% *flowering*	Plant height *(cm)*	No. of primary *branches/ plant*	No.of siliquae/ *plant*	1000 seed weight *(g)*	Yield/ *plant (g)*	Harvest index *(%)*
M 27/ TS 29	M	35	73	4.4	65.4	2.1	0.900	33.4
	H_1	-9.1*	15.9**	25.7**	60.9**	-4.5	155.6**	30.0**
	H_2	-	-	12.8	41.2**	-16.2**	121.8**	11.3
	sca	-0.67	-2.19	0.11	3.58	-0.1*	0.08	3.17
M 27/ OCPT 4	M	38	96	5.6	85.6	2.0	1.60	32.6
	H_1	-8.4*	28.0**	53.4**	109.8 **	2.5	292.6**	48.5**
	H_2	-	-	43.6**	84.9**	0.0	292.1**	44.9**
	sca	-0.95	8.67*	1.08**	35.03**	-0.06	0.72**	4.97*
M 27/ OCPT 4	M	37	98	4.8	85.4	2.6	1.105	28.3
	H_1	-6.3	32.4**	35.2**	100.2**	23.8**	143.5**	31.3**
	H_2	-	-	23.1*	84.4**	13.0*	121.0**	30.4*
	sca	0.47	12.81**	0.51**	22.79**	0.34**	0.21	0.75
M 27/ BT 1	M	33	80	3.9	54.0	2.1	0.739	30.3
	H_1	-18.5**	10.3**	8.3	21.7	-2.3	79.1**	47.4**
	H_2	-	-	0.0	16.6	-12.5**	77.2	41.6*
	sca	4.38**	-0.05	-0.17	-5.82	0.01	-00.12	2.18
TS 29 / OCPT4	M	36	98	5.4	73.0	2.7	1.10	26.2
	H_1	-10.0**	50.8**	66.1**	107.7 **	20.0 **	221.2**	-0.2
	H_2	-	-	58.8**	106.8**	8.0*	170.3**	-12.7**
	sca	-1.38	18.09**	1.27**	19.78**	0.44**	0.24*	-4.7*
TS 29/ PT 303	M	32	75	4.2	50.0	2.2	1.10	36.7
	H_1	-15.8**	17.2**	33.3**	35.1*	-8.3**	175.0**	42.0**
	H_2	-	-	31.2**	28.2	-12.0**	120.0**	22.3*
	sca	-2.95**	-2.76	0.30	-5.30	-0.26**	0.23	5.85**
TS 29/ BT 1	M	35	89	3.6	73.5	2.0	1.30	34.2
	H_1	-10.2**	42.4**	12.5	89.9**	-18.3**	262.6**	37.6**
	H_2	-	-	9.1	73.3**	-20.0**	211.7**	14.0
	sca	-0.81	16.38**	-0.08	20.98**	-0.28**	0.46**	2.78
OCPT 4/ PT 303	M	36	102	3.9	56.0	2.5	0.90	30.0
	H_1	-12.2**	34.2**	18.2**	50.7**	16.3**	98.4**	35.7**
	H_2	-	-	14.7	43.6*	8.7*	80.0*	33.3**
	sca	-2.24**	12.09**	-0.23	1.99	0.18**	-0.03	1.75
OCPT 4/ BT 1	M	39	76	3.7	37.6	1.8	1.00	38.5
	H_1	-7.1*	2.0	10.4	-3.2	-18.2**	142.7**	82.5**
	H_2	-	-	8.8	-11.3	-25.0**	139.8**	71.1**
	sca	-0.09	-8.76**	-0.21	-13.62**	-0.34**	0.10	9.68**
PT 303 / BT 1	M	35	86	4.5	68.0	2.5	1.40	33.3
	H_1	-12.5**	17.0**	38.5**	67.1**	6.4*	205.3**	60.9**
	H_2	-	-	36.4**	60.4**	4.2	180.0**	53.4**
	sca	- 1.67	3.38	0.18	14.69**	0.16**	0.49**	4.5*
SE (sij)		0.531	2.704	0.169	3.380	0.039	0.027	1.561
SE (sij-sik)		1.38	5.12	0.32	6.40	0.070	0.052	2.960
SE (sij-Skl)		1.26	4.68	0.29	5.86	0.065	0.048	2.699
CD (sij-sik) at 5%		2.82	10.48	0.65	13.11	0.143	0.106	6.060
CD (sij-skl) at 5%		2.58	9.58	0.59	12.00	0.133	0.098	5.530
r(M, H1)		0.85**	0.77**	0.93**	0.95**	0.51	0.93**	0.76*
r (M, H2)		-	-	0.85**	0.98**	0.91**	0.96**	0.53
r (M, sca)		0.75*	0.86**	0.95**	0.96**	0.93**	1.00**	0.68*

— Mean performance; H_1- Heterosis over mid-parent (%); H_2- Heterosis over better parent (%); *- Significant at P 0.05; **- Significant at P 0.01

Five open-pollinated rapeseed (*B. campestris* var. *toria*) varieties, eg., M-27, TS 29, OCPT 4, PT 303, and BT 1 were crossed in all possible combinations excluding reciprocals. These five parents along with ten hybrids were grown in a randomized complete block design with three replications during *rabi*, 2008-09. Each plot consisted of three rows of 2.0 m length, spaced 30 cm apart from row to row and 10 cm from plant to plant. Observations on 20 randomly selected plants were recorded on days to 50% flowering, plant height (cm), number of primary branches, siliquae/plant, 1000 seed weight(g), seed yield/plant (g) and harvest index (%). Heterosis over mid-parent (H_1) and over better parent (H_2) were estimated as per the method of Tumer (1953). Combining ability analysis was carried out following Griffing (1956).

The analysis of variance for combining ability indicated significant *sca* value at even 1% level of significance and invariably higher *sca* variance for all the characters. Most of the crosses also showed significantly higher *sca* effects and heterosis over both mid-parent and better parent for seed yield and important component traits (Table 2). This indicates predominance of non-additive gene action for almost all characters. High values of standard heterosis and heterobeltiosis have been also obtained by Prajapati *et al.*(2007) in Indian rapeseed, var. yellow *sarson*.

In the present experiment, none of the parents seems to be a good general combiner simultaneously for seed yield and important component traits (Table 1). The only variety, PT 303 had positive significant *gca* effect for seed yield, M 27 for number of branches/plant and siliquae/plant, TS 29 for harvest index, OCPT 4 for days to 50% flowering. Positive significant *gca* effect was also encountered for plant height in both OCPT 4 and PT 303 and for 1000 seed weight in TS 29 and PT 303. Thus, the above parents can be utilized for improvement of specific traits(s).

Most of the crosses matured significantly earlier than their respective parents as indicated by negative heterosis obtained over mid-parent (Table 2). This has a direct bearing on net returns/unit area/day. The best cross, M 27 x OCPT 4 showed appreciably high mean performance, heterosis and *sca* effect for number of branches/plant; siliquae/plant, seed yield/plant and harvest index. Another cross, TS 29 x OCPT 4 also appeared to be promising for seed yield and other component traits except harvest index.

Heterosis in case of 1000 seed weight ranged from -25.0 to 23.8%. Only three crosses, eg., M 27 x PT 303, TS 29 x OCPT 4 and OCPT 4 x PT 303 had significant positive heterosis over both mid-parent and better parent for this trait. Verma *et al.* (1989) reported moderate value of heterosis over better parent for test weight and harvest index in a set of crosses in Indian rapeseed. Further, it is interesting to note that heterosis increased with complexity of the trait, yield being the most complex trait exhibited maximum heterosis followed by number of siliquae/plant. This corroborates the findings of Katiyar *et al.* (2004) and Rai and Singh(1994). In the present study, crosses, e.g., M 27 x TS 29, M 27 x OCPT 4 and M 27 x BT 1 confer additive gene action for 1000 seed weight owing to their non-significant heterosis over mid-parent.

Barring non-significant correlation of mean performance with heterosis over mid-parent and that with heterosis over better parent in 1000 seed weight and harvest index respectively; mean performance had strong association with heterosis and sca for all the traits under study. Further, it is evident from table 1 that the mean yield performance exhibits a perfect association with *sca* (r=1.00). Therefore, mean performance for seed yield can be taken as a reliable indicator of *sca* in rapeseed and this can effectively be used for selection of best crosses in a set of material.

The present studies indicate that, in general, there is predominance of non-additive gene action in almost all the traits including seed yield/plant. This envisages good response for genetic improvement through heterosis breeding and recurrent selection leading to enhanced frequency of genetic recombination and widening the scope of exploitation of genetic variability through selection.

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Short communication

Genetic variability, heritability and genetic advance in sunflower, *Helianthus annuus* L.

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Abstract

The analysis of variance of 45 inbreds including checks revealed significant differences for all 10 characters studied. The characters studied were least affected by the environment showing a close correspondence between phenotypic coefficient of variation and genotypic coefficient of variation. High heritability coupled with the high genetic advance was recorded for plant height, seed yield/plant, husk content percentage and seed filling percentage. High heritability with the low genetic advance was observed for 100 seed weight, oil content, days to 50% flowering, days to maturity, volume weight, and head diameter suggesting that, these characters cannot be effectively improved by selection.

Keywords: *Sunflower, variability, heritability and genetic advance*

The development of an effective plant breeding programme is depending upon the existence of genetic variability. Hence, an insight into the magnitude of variability present in gene pool of a crop species is of utmost importance to plant breeder for starting a judicious plant breeding programme. A wide range of variation has been reported for seed yield in sunflower (Dash *et al.*, 1996) and other important components of yield (Reddy *et al.*, 2004). Therefore, the present study was undertaken to study the genetic variability, heritability and genetic advance in 45 inbreds of sunflower.

The material consisting of 45 inbreds including three checks were grown in randomized block design with three replication during *kharif*, 2006 at Oilseed Research Station, Latur. The inbreds were grown in a row of 4.5 m length with spacing of 60 cm and 30 cm between rows and plants, respectively. Recommended cultural, agronomical practices and plant protection measures were followed for healthy crop growth during whole season. Five randomly selected plants per genotype per replication were used for recording observations *viz.*, days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), filled seeds/head, 100 seed weight (g), husk content (%), volume weight (g/100 ml), seed yield/plant (g) and oil content (%). The oil content of seeds was estimated with the help of nuclear magnetic resonance. The genetic parameters of variability, estimation of heritability and genetic advance were computed according to the method suggested by Johnson *et al.* (1955). The analysis of variance revealed significant differences for all the characters studied. The range of variation was maximum for plant height, followed by husk content, filled seeds, seed yield/plant and days to 50% flowering while it was lowest in case of 100 seed weight, head diameter, volume weight and oil content.

Table 1 **Range, mean, phenotypic and genotypic variance, phenotypic and genotypic coefficients of variation, heritability and genetic advance for different characters in sunflower**

Character	Range			Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability (h^2bs) (%)	Genetic advance (GA)
	Min.	Max.	Mean						
Days to 50 % flowering	44.66	65.66	55.16	15.69	13.88	7.18	6.75	88.46	7.21
Days to maturity	84.66	100.00	92.33	16.21	13.08	4.6	3.91	80.69	6.69
Plant height (cm)	71	155	113	326.60	323.85	15.99	15.92	99.15	36.91
Head diameter (cm)	10	17	13.5	3.64	2.31	14.13	11.25	63.46	2.49
Percentage of filled seeds/head	54.33	78.66	66.49	29.01	26.65	8.10	7.76	91.86	10.19
100 seed weight (g)	2.95	7.00	4.97	1.06	0.98	20.71	19.91	92.45	1.96
Husk content (%)	13.66	42.33	27.99	44.98	43.40	26.68	23.53	96.48	13.33
Volume weight (g/100 ml)	34.66	46.66	40.66	10.09	7.80	7.81	6.86	77.30	5.05
Seed yield/plant (g)	15.33	38.66	26.99	46.23	45.18	25.24	24.95	97.73	13.71
Oil content (%)	23.84	37.83	30.83	14.48	12.92	12.34	11.65	89.22	6.99

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

The results showed a close correspondence between the phenotypic and genotypic variances for all the characters indicating stable expression of the attributes and absence of high environmental influence.

High heritability values coupled with high genetic advance were recorded for plant height, seed yield/plant, husk content and filled seeds % indicating that these characters are governed by additive gene action and directional selection for these traits would be more effective for desired genetic improvement. Similar results were reported by Muhammad *et al.* (2007). High heritability accompanied with low genetic advance was noticed in rest of the characters like 100 seed weight, oil content percentage, days to 50% flowering, days to maturity, volume weight, seed filling percentage and head diameter suggesting that the variation was probably due to non-additive gene effects suggesting limited scope for improving these characters through phenotypic selection.

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Short communication

Heterosis in three-way cross hybrids of sunflower, *Helianthus annuus* L.

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Abstract

Thirty three-way cross (TWC) hybrids were obtained using three male sterile single cross hybrids *viz.*, DCMS (I A x 9B), DCMS (1A x 2B) and DCMS (4A x 12B) and 10 restorer lines *viz.*, DRS 5, DRS 8, DRS 9, DRS 16, DRS 21, DRS 22, DRS 27, DRS 28, DRS 33 and DRS 35 to study the magnitude of heterosis over mid-parent, better parent and standard checks *viz.*, KBSH-I and KBSH-44 during summer, 2006 in sunflower at Directorate of Oilseeds Research, Rajendranagar, Hyderabad. The study revealed that different hybrids exhibited varied magnitude and direction of heterosis for different characters. The TWC hybrids, (DCMS 1A x 2B) x DRS 21 and (DCMS 1A x 2B) x DRS 9 showed highest positive standard heterosis over KBSH-44 regarding seed yield/plant. These hybrids also recorded maximum positive heterosis for head diameter, number of filled seeds/head and 100 seed weight. Hybrid, (DCMS 1A x 9B) x DRS 27 exhibited the highest heterosis percentage for oil content. The TWC hybrid, (DCMS 1A x 9B) x DRS 22 exhibited highest negative standard heterosis over KBSH-1 and KBSH-44 for days to maturity and the hybrids, (DCMS 1A x 2B) X DRS 35 and (DCMS 1A x 2B) x DRS 22 displayed maximum heterosis for earliness.

Keywords: Sunflower, heterosis, three-way cross hybrids, yield components

Sunflower is one of the most important edible oilseed crops in India. Due to its wider adaptability, short duration and better oil quality with high polyunsaturated fatty acid content (PUFA), it has become a popular crop in India. Sunflower, being a cross-pollinated crop, is more amenable for the exploitation of heterosis. Single cross (SC) hybrids have been widely used as commercial cultivars in India that results in increased homogeneity with narrow genetic base, thus creating genetic vulnerability and yield of single cross hybrids is fairly stagnant over recent years. The production of three-way cross (TWC) hybrids has been thought to be a viable alternative to break the yield plateau. Three-way cross hybrids are of recent origin in sunflower. Cytoplasmic male sterile line (A-line) is crossed with an unrelated maintainer line (B-line) to produce a male sterile single cross hybrid. This hybrid is crossed with a fertility restorer line (R-line) to produce a male fertile TWC hybrid for commercial use. Three-way cross hybrids provide advantages like lower seed cost, broad genetic base to sustain environmental fluctuations and opportunity to incorporate additional lines which are resistant to diseases. In order to evaluate the performance of TWC hybrids, a study was undertaken to estimate the extent of heterosis in respect of yield and yield attributes.

Three cytoplasmic male sterile single cross hybrids *viz.*, DCMS (1A x 9B), DCMS (1A x 2B) and DCMS (4A x 12B) which were developed at Directorate of Oilseeds Research, Hyderabad were crossed with 10 restorer lines *viz.*, DRS 5, DRS 8, DRS 9, DRS 16, DRS 21, DRS 22, DRS 27, DRS 28, DRS 33 and DRS 35 to produce 30 TWC hybrids. These hybrids along with their 13 parents (three maintainer lines of single cross male sterile hybrids and 10 fertility restorer lines) and two checks were evaluated using randomized block design with three replications during summer, 2006 at Directorate of Oilseeds Research, Rajendranagar, Hyderabad.

Each entry was sown in three rows of 4.5 m length with a uniform spacing of 60 cm x 30 cm. Recommended package of practices was adopted to a raise healthy crop. Observations were recorded at appropriate stages on five randomly selected plants in each treatment in all replications for days to 50% flowering, days to maturity, head diameter (cm), number of filled seeds/head,100 seed weight (g), seed yield/plant (g) and oil content (%). Oil content was determined by using nuclear magnetic resonance spectrometer. Heterosis was worked out over mid-parent, better parent and over standard checks, KBSH-1 and KBSH-44.

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The analysis of variance revealed highly significant differences among the parents as well as hybrids for all the traits. The results indicated the presence of significant amount of heterosis for all the traits. Estimates of heterosis, heterobeltiosis and standard heterosis for best selected hybrids are presented in table 1.

Among 30 TWC hybrids, 29 hybrids over KBSH-1 and all over KBSH-44 showed significant negative standard heterosis in which the hybrid, [(DCMS 1A x 9B) x DRS 21] displayed highest negative standard heterosis over KBSH-44 for days to 50% flowering. Twenty nine hybrids over KBSH-1 and KBSH-44 showed significant negative standard heterosis for days to maturity. For days to 50% flowering and days to maturity, hybrids [(DCMS 1A x 2B) x DRS 35] and [(DCMS 1A x 9B) x DRS 22] showed the highest average heterosis and standard heterosis respectively in negative direction is considered desirable since earliness is preferred over late maturity. Present findings are in agreement with the results of Alone *et al.* (2003) and Manivannam *et al.* (2005). Regarding head diameter, 19 hybrids, out of 30 hybrids exhibited positive heterosis and the hybrid, [(DCMS 1A x 2B) x DRS 21] recorded highest positive heterosis. None of the hybrids exhibited positive standard heterosis over KBSH-1 and KBSH-44 for this trait (results not given).

Table 1 Heterosis, heterobeltiosis and standard heterosis of superior hybrids over KBSH-1 and KBSH-44 for yield and its component characters

Character	Hybrids	Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%)	
				KBSH-1	KBSH-44
Days to 50% flowering	(DCMS 1A x 2B) x DRS 35	-19.03**	-19.68**	-15.64**	-19.68**
	(DCMS 1A x 2B) x DRS 33	-15.79**	-17.84**	-15.08**	-19.15**
	(DCMS 1A x 2B) x DRS 22	-15.24**	-17.30**	-14.53**	-18.62**
	(DCMS 1A x 2B) x DRS 27	-13.31**	-17.30**	-14.53**	-18.62**
Days to maturity	(DCMS 1A x 9B) x DRS 22	-10.61**	-11.94**	-16.01**	-16.61**
	(DCMS 1A x 2B) x DRS 35	-10.53**	-10.53**	-9.25**	-9.89**
	(DCMS 1A x 2B) x DRS 22	-10.31**	-12.98**	-11.74**	-12.37**
	(DCMS 1A x 2B) x DRS 16	-10.17**	-14.74**	-13.52**	-14.13**
Head diameter	(DCMS 1A x 2B) x DRS 21	28.90**	6.88	3.15	-0.24
	(DCMS 1A x 9B) x DRS 22	23.94**	9.03	-6.8	-9.87*
	(DCMS 1A x 9B) x DRS 33	21.87**	17.20**	0.18	-3.11
	(DCMS 1A x 2B) x DRS 9	21.84**	4.29	0.64	-2.67
No. of filled seeds	(DCMS 1A x 2B) x DRS 21	124.37**	70.85**	22.64**	33.85**
	(DCMS 1A x 2B) x DRS 9	104.61**	71.60**	23.19**	34.44**
	(DCMS 1A x 9B) x DRS 21	88.87**	52.37**	-6.78	1.74
	(DCMS 1A x 9B) x DRS 8	88.52**	52.90**	-6.45	2.09
100 seed weight	(DCMS 4A x 12B) x DRS 33	48.22**	35.98**	23.20**	18.87**
	(DCMS 1A x 2B) x DRS 9	41.96**	28.24**	19.70**	15.50**
	(DCMS 1A x 2B) x DRS 21	34.59**	15.29*	7.62	3.84
	(DCMS 4A x 12B) x DRS 21	32.58**	15.00*	4.19	0.53
Seed yield/plant	(DCMS 1A x 2B) x DRS 21	151.35**	65.33**	39.44**	45.53**
	(DCMS 1A x 2B) x DRS 9	142.87**	72.53**	45.51**	51.86**
	(DCMS 4A x 12B) x DRS 33	111.98**	78.72**	36.84**	42.81**
	(DCMS 1A x 9B) x DRS 33	100.50**	83.71**	15.93	20.99*
Oil content	(DCMS 1A x 9B) x DRS 27	36.29**	11.81**	1.26	7.78*
	(DCMS 1A x 9B) x DRS 9	31.02**	-0.84	-10.20**	-4.41
	(DCMS 4A x 12B) x DRS 9	30.35**	-2.21	-9.07**	-3.22
	(DCMS 1A x 2B) x DRS 9	28.68**	-4.66	-7.95**	-2.02

Twenty four hybrids showed significant positive heterosis in which the crosses *viz.*, [(DCMS 1A x 2B) x DRS 21], [(DCMS 1A x 2B) x DRS 9] and [(DCMS 1A x 9B) x DRS 21] recorded high heterosis and heterobeltiosis for number of filled seeds/head. These results are in accordance with the previous findings of Goksoy *et al.* (2000), Phad *et a* (2002) and Loganathan and Gopalan (2006). For 100-see weight, TWC hybrid, (DCMS 4A x 12B) x DRS 33 exhibite highest positive significant heterosis, heterobeltiosis ar standard heterosis over KBSH-1. Among 30 hybrids, three hybrids over KBSH-1 and two hybrids over KBSH-44 exhibited standard significant positive heterosis for this trait.

Hybrids, [(DCMS 1A x 2B) x DRS21], [(DCMS 1A x 2B) x DRS 9] and [(DCMS 4A x 12B) x DRS 33] showed very high heterosis. Hybrids, [(DCMS 1A x 2B) x DRS 9] and (DCMS 1A x 2B) x DRS 21 manifested very high standard heterosis over KBSH-1. Similar results were reported by Alone *et al.* (2003), Loganathan and Gopalan (2006) and Parameshwarappa *et al.* (2008) for standard heterosis.

For oil content, the crosses, [(DCMS 1A x 9B) x DRS 27], [(DCMS 1A x 9B) x DRS 9] and [(DCMS 4A x 12B) x DRS 9] recorded very high heterosis. The results are in accordance with Alone *et al.* (2003) and Loganathan and Gopalan (2006).

It is interesting to note that different hybrids exhibited different magnitude of heterotic effects for different characters, no single cross exhibited desirable significant heterosis for all the characters (Table 1). Some of the hybrids in which (DCMS 1A x 2B) was involved as a female parent exhibited highest desirable heterosis for days to 50% flowering, head diameter, number of filled seeds/head and seed yield/plant. Whereas, among the testers, DRS 9, DRS 21 and DRS 33 were involved as male parents in most of the top hybrids for heterosis for head diameter, number of filled seeds/head, 100 seed weight, seed yield/plant and oil content. This indicated the presence of higher frequency of additive alleles in these one female and two male parents.

Further, it gives an indication of good general combining ability of these lines for these characters. The TWC hybrids, (DCMS 1A x 2B) x DRS 21, (DCMS IA x 2B) x DRS 9, (DCMS 4A x 12B) x DRS 33 and (DCMS 1A x 9B) x DRS 33 were found superior to commercial check variety KBSH-44 in respect of seed yield/plant. The main reason ascribed is diversified parents involved in the cross combination or uncommon genes for traits and the superior performance of TWC hybrids is attributed to the favourable epistatic interaction of the genes from the three parental lines which resulted in maximum exploitable level of heterosis. This can be attributed to the buffering action against adverse environmental conditions as TWC hybrids are characterized by highly heterozygous and heterogenous condition. Hence, these promising hybrids have wide scope and need to be tested in large scale trials and also at different locations to confirm their superiority and stability across locations.

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Short communication

Effect of sulphur sources and levels on the productivity of sunflower, *Helianthus annuus* L.

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Abstract

A field experiment was carried out during *kharif* 2007 at ZARS, UAS, GKVK, Bengaluru, Karnataka to find out the effect of sulphur, for maximizing the sunflower seed yield and oil content. The results showed that the use of sulphur sources and levels did not influence yield attributes *viz.*, plant height, head diameter, stem diameter, seed yield, oil content and net returns.

Keywords: Sunflower, economics, oil content, sulphur sources, seed yield, KBSH-41

In India, sunflower (*Helianthus annuus* L.) is an important edible oilseed crop with 40-42% of oil content. Sulphur is required to synthesize the sulphur containing amino acids and proteins, activity of proteolytic enzymes and increases oil content in oil bearing plant. Sulphur deficient plant produces less protein and oil. Sulphur deficiency in sunflower (*Helianthus annuus* L.) is detrimental to seed yield and quality (Hocking *et al.*, 1987). For obtaining maximum crop yields with maximum benefit to the growers, it is most essential that the crop should be fed properly with all the nutrients. A field experiment was conducted to find out the effect of levels and sources of sulphur on the seed yield and oil content of sunflower. The sunflower hybrid KBSH-41 was grown in *kharif* 2007 using randomized block design with three replications and a spacing of 60 cm x 30 cm. Plot size was 4m x 5.2 m. Four sources of sulphur (Ammonium sulphate, gypsum, single super phosphate and elemental sulphur) were evaluated at two levels (20 and 40 kg S/ha) along with a control. The soil of the experimental site was red sandy loam in texture. The initial soil fertility was slightly acidic (pH: 5.7) reaction with normal EC (0.17dS/m) and low in organic carbon (0.35%). The soil available phosphorus, nitrogen and potassium content were 137.8, 282.2 and 249.6 kg/ha, respectively. The available sulphur (59.9 kg/ha) content was very high.

A fertilizer dose of 60:75:60 kg N, P_2O_5 and K_2O/ha, respectively was applied to all the plots at the time of sowing. Half the dose of N was applied as basal and the remaining half at 30 DAS. Need-based crop protection measures were taken. The oil content in seeds was determined by NMR method. The yield attributes, yield and economic parameters were studied to evaluate the effects and the data was analysed statistically.

The results indicated that most of the yield components (plant height, head diameter and stem girth) and seed yield of KBSH-41 did not differ significantly with various sulphur levels and sources (Table 1). This is in agreement with the groundnut experiment findings reported by Patel *et al.* (2008). This effect may be attributed to a higher level of sulphur in the soil, resulting in lesser response to applied sulphur. The nonsignificant response in this study may be due to higher soil available S content. Similar findings have been reported by Virender Sardana *et al.* (2007). However, a decreasing trend in seed yield towards higher level of different sources of sulphur application was observed. But, treatment with 20kg S/ha through gypsum recorded highest seed yield (1588 kg/ha) closely followed by control (1557 kg/ha).

The oil content did not differ significantly against the treatments (Table 1). A similar finding was also reported by Hocking *et al.* (1987) and Verinder Sardana *et al.* (2007). The oil yield followed the trend observed in seed yield. Application of 20 kg S/ha through gypsum recorded maximum net returns (Rs 19,951/ha), harvest index (0.34) and benefit cost ratio (1.95). Elemental sulphur recorded very low returns. In groundnut crop, elemental sulphur proved inferior to gypsum (Naphade and Wankhede, 1988), which could be due to slow oxidation of elemental sulphur (Arora *et al.*, 1987).

Based on the results of the experiment, it can be concluded that under high soil available S status Alfisols, response to S for yield attributes and oil content was not significant.

Table 1 Effect of different sources and levels of sulphur on the productivity and economics of KBSH-41

Level of sulphur (kg/ha)	Source of sulphur	Plant height (cm)	Head diameter (cm)	Seed yield (kg/ha)	Oil (%)	Oil yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
0	Control	189.5	15.2	1557	37.4	582	29575	19544	1.95
20	Ammonium sulphate	196.2	16.1	1500	34.3	514	28498	17631	1.62
	Single super phosphate	199.4	16.3	1466	36.1	529	27850	17669	1.74
	Gypsum	200.5	15.5	1588	37.1	589	30169	19951	1.95
	Elemental sulphur	196.5	15.3	1304	33.6	438	24768	9263	0.60
40	Ammonium sulphate	194.2	15.6	1431	33.0	472	27191	15479	1.32
	Single super phosphate	193.0	14.5	1326	36.4	482	25196	14869	1.44
	Gypsum	191.8	14.3	1268	38.2	484	24097	13692	1.32
	Elemental sulphur	193.7	15.2	1363	36.0	490	25896	4917	0.23
SEm±		4.25	0.42	118	1.59				
CD(P=0.05)		*NS*	*NS*	*NS*	*NS*				

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Short communication

Large-scale evaluation for improving sunflower yield through honey bee pollination

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Abstract

Studies on large-scale evaluation for improving sunflower yield through honey bee pollination were made in 28.6 ha cropped area during *kharif*, *rabi* and summer season of 2002 and 2003. The sunflower crop pollinated with five *Apis mellifera* L. bee colonies/ha, produced significantly highest mean additional seed yield of 368 kg/ha which accounted to 42.2% increase over the crop without bee colonies. Significant increase in seed filling and seed weight contributed to the enhancement of yield. It is concluded that five *A. mellifera* bee colonies/ha are required for optimum pollination and improving the sunflower yield.

Keywords: Sunflower pollination, *Apis mellifera*

Sunflower (*Helianthus annuus* L.) is an important oilseed crop grown in an area of 2.4 million ha with a production of 1.44 million tonnes in India (Anonymous, 2007). The productivity of sunflower is as low as 680 kg as against the world productivity of 1170 kg/ha (Seetharam, 2003). However, this productivity can be increased to an extent of 45 to 60% through management of bee pollination (Melnichenko and Khalifman, 1960). The role of pollinators especially honey bees in increasing the productivity is well documented throughout the world. Though Karnataka is one of the major states growing sunflower, there is no recommendation on the colony requirement for optimum pollination for maximizing the yield. Viraktamath and Patil (2002 and 2003) conducted studies on improving sunflower yield under caged conditions followed by a small scale field experiment and found that five bee colonies of *Apis mellifera* L./ha are required for optimum pollination and increasing the yield. In order to validate these results a large-scale field experiment under protected irrigation and rainfed conditions were conducted and the results of these studies are presented in this paper.

These experiments were conducted at three locations at Mundargi under protected irrigation and under rainfed condition in two locations at Asundi and one location each at Harti and Kanavi during *kharif* and *rabi* seasons of 2002-03, covering a total area of 28.6 ha. In each location, there were two treatments *viz.*, crop pollinated by five bee colonies/ha (T_1) and crop without bee colony (T_2) which served as a control and these treatments were separated by >1.0 km from each other. The ruling hybrids like KBSH-1 and Agsun[R] were selected in different locations but the same hybrid was used in each set of the treatments. The experimental plot size for each treatment varied from 0.8 to 4.4 ha and each of these plots was divided into eight equal subplots which were treated as eight replications. The required number of colonies was moved to the experimental fields at the initiation of the flowering and these colonies were kept evenly distributed in the plot. The colonies remained at the field till complete flowering was over. Observations were made on the yield in all the locations. But observations on the per cent seed filling, 100 seed weight and oil content were made only at Asundi. The data were subjected to "t" test to compare the significance of the means among the treatments.

The yields at Mundargi were 2250, 2375 and 2125 kg/ha at location 1, 2 and 3, as against 1875, 1750 and 1700 kg/ha in the control plots, respectively (Table 1). Thus there was an increase of 20, 35.7 and 25.0% in the yield due to pollination by the bees.

At Harti, the yield was 1250 kg/ha in the bee-pollinated crop as against 1000 kg/ha in the control. This accounted to an increase of 25% in the bee pollinated crop and a benefit of Rs. 3750/-. Similarly at Kanavi, bee pollinated crop yielded 1550 kg/ha, which was 55% higher than the yield in the control plot (1000 kg/ha) resulting in benefit of Rs. 8250/- due to the incremental yield. (Table 1)

At Asundi, bee pollination resulted in the yield of 425 and 450 kg/ha at location 1 and 2, respectively, which accounted to an increase of 54 and 80% over the control at location 1 (275 kg/ha) and location 2 (250 kg/ha), respectively. The low yield at Asundi compared to other areas was due to the severe moisture stress as the rains failed during the season.

Increase in yield in the bee-pollinated crop was clearly due to the increase in seed filling and seed weight. Bee pollination resulted in higher seed filling of 94.88 and 92.25% at location 1 and 2 at Asundi, respectively, as against 84.5 and 85.5% in control (Table 2). Thus, there was an enhancement to the extent of 12.28 and 7.89% in seed filling due to bee pollination. Similarly bee pollinated seeds were significantly heavier (4.3 and 4.46 g /100 seeds) as against 3.5 and 3.69 g in control which accounted to an increase of about 21%. However, the percent germination of seeds did not vary.

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Table 1 Effect of bee pollination on yield of sunflower in different locations during 2002-03

Place of experiment and hybrid	Locations	Season	Treatments	Yield (kg/ha)
Mundargi (Agsun)	Location 1	*Kharif*	T_1 (with 5 bee colonies/ha)	2250*
			T_2 (without bee colonies)	1875
Mundargi (Agsun)	Location 2	*Kharif*	T_1	2375*
			T_2	1750
Mundargi (Agsun)	Location 3	Summer	T_1	2125*
			T_2	1700
Harti (KBSH-1)	Location 1	*Kharif*	T_1	1250*
			T_2	1000
Kanavi (KBSH-1)	Location 1	*Kharif*	T_1	1550*
			T_2	1000
Asundi (KBSH-1)	Location 1	*Rabi*	T_1	425*
			T_2	275
Asundi (KBSH-1)	Location 2	*Rabi*	T_1	450*
			T_2	250

* Significant higher by T test

Table 2 Effects of bee pollination on yield parameters at Asundi during 2002-03

Treatment	Yield (kg/ha)		Seed filling (%)		100 Seed weight (g)		Germination (%)	
	Location 1	Location 2	Location 1	Location 2	Location 1	Location 2	Location 1	Location 2
T_1 : Crop pollinated with 5 bee colonies /ha	425	450	94.88	92.25	4.3	4.46	96.0	96.0
T_2 : Crop without any colony – Control	275	250	84.50	85.50	3.50	3.69	96.0	96.0
T value	*5.3563**	*6.2142**	*5.1097**	*3.7914**	*4.0326**	*5.4302**	*NS*	*NS*

* Significant higher by T test; NS = Non-significant

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Short communication

Life cycle of red rust flour beetle, *Tribolium castaneum* (Herbst.) (Coleoptera:Tenebrionidae) on seeds of sunflower, *Helianthus annuus* L.

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Abstract

The red rust flour beetle, *Tribolium castaneum* is an important pest of stored seeds of sunflower. The pest laid the eggs singly on the cracks and crevices of seeds. On an average, each life stage *viz.*, egg, first, second, third, fourth, fifth, sixth larval instars *and* pupal period lasted for 6.07±0.86 , 2.23±0.43, 6.15±0.55, 4.30±0.48, 5.83±0.75, 6.38±0.96, 16.9±1.89 and 8.01±1.95 days, respectively. The oviposition started after a period of 5.1±0.99 days after mating and lasted for 120.3±5.47 days. Female beetles laid 81.1±9.57 eggs. Adults lived for more than 140 days when food was provided.

Keywords: Sunflower, *Tribolium castaneum*, biology

In India, sunflower (*Helianthus annuus* L.) is cultivated over an area of 2.16 m.ha., with an annual production of 1.22 m. tonnes. Karnataka accounts for a sunflower area of 1.23 m.ha. with an annual production of 0.52 m. tonnes (Anonymous, 2008). The predominant insect-pest fauna of stored sunflower include, saw toothed beetle, *Oryzaephilus surinamensis* (L.), red rust flour beetle, *Tribolium castaneum* (Herbst.) and the rice moth, *Corcyra cephalonica* Stainton which cause severe damage to the stored sunflower (Mc Bride, 1981). Though much work has been done on field pests, the investigations, particularly on storage insect-pests of sunflower is lacking. Therefore, the present study was conducted to study the biology of *T. castaneum* on sunflower, which has not been studied so far.

The current investigation revealed that *T. castaneum* fails to develop on whole grains of sunflower, hence , its biology was studied on broken sunflower seeds under laboratory conditions (cv.KBSH-44). Detailed observations were made on its life history parameters. One pair of adult beetles each were introduced into 25 glass vials containing sunflower seeds . The eggs laid by the adult female were counted in order to know the fecundity of the beetle, the seeds which received egg laying were replaced with uninfested seed at frequent intervals. The eggs were kept for further observation till the hatching of the first instar larva. The duration (in days) from the time of emergence of first instar larva till the formation of the pupal cocoon was recorded. The time lapse between one moult to the next moult was recorded, from which the duration of individual larval instars was computed and expressed in days. The period from when the inactive non-feeding stage commenced till the formation of the pupa was recorded. This duration was expressed as pre -pupal period. The time that lapsed from the formation of pupa till the emergence of adults was recorded and expressed as pupal period.

A separate experimental setup was maintained to study the pre-oviposition, oviposition period and the fecundity. One pair of freshly emerged adult beetles each were introduced into 25 glass test tubes (15 cm x 1.5 cm. size) containing 2 g of seeds each. Observations were recorded on a daily basis. The time of commencement of oviposition was recorded, the number of eggs that were deposited was counted once in three days and hence the total number of eggs laid by each female was computed. The life span of adult beetles, both in the presence and absence of food, was observed by enclosing male and female beetles into separate glass vials, 25 replications were maintained for the study.

The egg was oblong in shape, measuring about 0.65 mm in length and 0.30 mm in width, the shell was smooth, unmarked rather thin and pliable and covered with sticky substance which helps in attachment of eggs to the seeds and also to the cracks and crevices of the seeds and any other substrata available in the vicinity. Incubation period of eggs ranged from 5 to 7days, (mean = 6.07 days). These findings are in agreement with the observations made by Singh *et al.* (2006). Irrespective of the sex, the larvae passed through six instars. The larval instars later entered into non-feeding quiescent stage and finally pupation occurred in the food media itself, within the containers. The first instar larvae were slender, cylindrical, having white colour with yellowish tinge and light brown coloured head capsule. They were oligopod type with three pairs of segmented thoracic legs, while abdominal legs were absent. They measured 1.11 mm in length and 0.80mm in width. The duration of this instar was found to be 2 to3 days (mean = 2.23 days) (Table 1)

Table 1 Life history parameters of *T. castaneum* on sunflower seeds

Stage of life cycle	Duration (in days)		
	Minimum	Maximum	Mean ± SD
Egg	5	7	6.07 ± 0.86
Larval instars			
1	2	3	2.23 ± 0.43
2	6	7	6.15 ±0.55
3	4	5	4.30 ±0.48
4	5	7	5.83 ± 0.75
5	5	8	6.38 ±0.96
6	14	19	16.9 ±1.89
Total larval period	36	49	40.98±5.06
Pupa	6	13	8.01 ± 1.95
Total life cycle	50	62	56.30± 4.11

The second instar larvae had a yellowish tinge on the cuticle, which was more pronounced than that of the first instar and the head capsule appeared much darker than the remaining segments. The second instar duration ranged between 6 and 7 days (mean = 6.15 days). The mean length of the second instar larva was 1.40 mm and its breadth was 0.25 mm. The third instar larvae appeared similar to the second instar larvae, except for their size. The larvae had the ability to feed on broken kernels of sunflower and mandibles became much stronger as compared to earlier instars. The duration of this instar varied from 4 to 5 days, with a mean of 4.3 days. The third instar larva measured 1.98 mm in length and 0.30 mm in width. The fourth instar larvae were similar in their shape and colour with the preceding instars, except in case of its size, which measured about 2.37 mm in length and 0.32 mm in width. The mean duration of fifth instar was about 5.83 days with a range of 5 to7 days. The fifth instar larvae were similar in their features to that of the other instars, except for their size and the well developed head capsule. The average length of the fifth instar larva was 3.04 mm and its width was 0.45 mm, while its duration ranged from 5 to 8 days, (mean= 6.38 days). The sixth instar larvae were 3.49 mm in length and 0.52 mm in width, colour was white tinged with yellow, with dorsal part of the of the head capsule, tips of the claw and all the terga of all the segments slightly darkened, urogomphi and tips of the mandible testaceous, the form was elongate, cylindrical about eight times as long as wide, dorsally convex, ventrally slightly flattened ninth abdominal segments were clothed with yellowish tactile hairs body was provided with the few long, thin, yellowish setae, those on the ninth abdominal segments were more numerous.

The pupation was preceded by a non-feeding, inactive pre-pupal stage of about 2 to 3 days, which moulted into an exarate pupa, with laterally placed wing pads and ventrally placed legs and mouth parts. The male and female pupae were distinguished by their characteristic genital segments, which in male was having a flat disk like depression, whereas in the female, two cone like appendages were seen which were similar to the urogomphi, but much shorter and relatively thicker. Pupa was white in colour but within a day or two, it acquired yellowish tinge, which darkened later and the eyes turned dark brown. Pupa measured 3.3 mm in width and 0.33 mm in length, the pupal period ranged from 6 to13 days, with a mean of 8.01 days. These findings are in agreement with the observations made by Urs and Mukherjee (1966) and Singh *et al.* (2006), but do not agree with those of Hasan and Khan (1988) on lentil flour, which could be due to the differences in the host used, as well as the variations in geographic location of the experimentation.

The male and female adult beetles after emergence needed a pre-mating period of 1 to 2 days (mean=1.7 days) before the occurrence of first mating. The mean duration of mating was observed to be 9.77 min., with a range of 8 to 13 min. However, the mating continued frequently throughout the life period (Table 1).

The pre-oviposition period ranged from 4 to 6 days(mean = 5.1 days). The oviposition period ranged from 110 to 124 days(mean duration =120.3 days). The number of eggs laid by the adult beetles ranged from 69 to 89 (mean= 81.11 eggs/female). After the completion of the egg laying, adult beetles could live for 7 to 9 days (mean=8.01). These findings were also corroborated by those of Singh *et al.* (2006). The longevity of virgin adult male and female beetles (without food) ranged from 18 to 21 days (mean=19.11 days). However, they lived more than 140 days when enclosed in vials containing sunflower seeds (Table 2). Adults were small sized, reddish, measured about 3.5 mm in length, with elytra striated. Newly emerged adults were soft and colourless, which acquired colouration and hardness after some time. These findings were in concurrence with that of Singh *et al.* (2006).

Table 2 Mating, ovipositional period and adult longevity of *T. castaneum* on sunflower seeds

Stage of life cycle	Range		
	Minimum	Maximum	Mean± SD
Pre-mating period (in days)	1	2	1.70±0.48
Mating period (in minutes)	8	13	9.77± 1.82
Pre oviposition period (in days)	4	6	5.1± 0.99
Oviposition period (in days)	110	124	120.3±5.47
Post oviposition period (in days)	7	9	8.01±1.13
Adult longevity with food (in days)			>140 days
Adult longevity without food (in days)	18	21	19.11±1.52
Fecundity (eggs/female)	69	89	81.1± 9.57

The findings of the present investigation will help in better understanding of the pest's life cycle, which will pave the way for formulating sound management strategies for *Tribolium* in stored sunflower.

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Short communication

Evaluation of certain eco-friendly insecticides against insect-pest complex of sunflower, *Helianthus annuus* L.

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Abstract

A field experiment on the evaluation of eco-friendly insecticides against major insect-pests of sunflower was carried out during *rabi*, 2007-08. Among the treatments, spinosad 45 SC (0.015%) was found very effective against *Spodoptera litura* (Fab.)with 51.0% mean reduction in larval population over untreated check, while efficacy of azadirachtin-based neem formulation against sucking pests *viz.*, Neemazal 0.03% was significantly superior over all the other treatments with 38.2, 37.1 and 6.8 % mean reduction in *Amarasca biguttula biguttula* (Ishida), *Bemisia tabaci* (Gennadius) and *Aphis craccivora* (Koch) population over untreated check, respectively. Spinosad 0.015% applied sunflower crop produced significantly highest yield of 1658 kg/ha over untreated check.

Keywords: Ecofriendly insecticides, sunflower, insect pests

Sunflower (*Helianthus annuus* L.) is a promising oil seed crop next to groundnut and soybean in India, which faces the attack of 251 insects and acarine species throughout the world (Rajmohan *et al.*, 1974). Many broad spectrum insecticides are being used intensively and indiscriminately by farmers for management of these pests which lead to several problems like pest resurgence, insecticidal resistance in key pest species, secondary pest out break, pesticide residues in food chain, degradation in the quality of eco-system and human health. Hence, keeping these problems in view, a field experiment for the evaluation of eco-friendly insecticides against major insect pests of sunflower was carried out to develop sustainable and environmentally safe pest management methods.

An experiment was laid out on sunflower cv APSH-11 during *rabi* season, 2007-08 in a randomized block design (RBD) with 11 treatments replicated thrice in a plot size of 15 m^2 (5 m x 3 m). The crop was grown under recommended agronomic practices except insect-pests management. The treatments were applied twice at 65 and 80 days after sowing of the crop using hand compression sprayer. Observations on the pest intensity were recorded at one day before spraying as pre-treatment count and at 1, 5, 10 and 15 days after spraying as post treatment count. Total number of larvae of *S. litura* were recorded on 10 randomly selected and tagged plants, while population of leafhopper nymphs and adults, whitefly and aphid were counted during early morning hours on five leaves (top two, middle one, bottom two) on same plants. Overall population reduction in different treatments over untreated check was calculated as per Flemming and Ratnakaran (1985). The data on pest intensity and yield of sunflower from each treatment were analysed statistically.

All the treatments were significantly effective in bringing down the larval population of *S. litura* over untreated check. Among the treatments, spinosad 45 SC (0.015%) was significantly superior over all the other treatments with 51.0% mean reduction in larval population over untreated check followed by B.t.k. (36.5%) and Sl NPV (34.9%) while remaining treatments could provide below 30% reduction in its population (Table 1).

Reduction in mean population of sucking pests was higher in neem-based formulations. Application of Neemazal 0.03% was significantly superior over all the other treatments with 38.2, 37.1 and 6.8 % mean reduction in *A. biguttula biguttula*, *B. tabaci* and *A. craccivora* population over untreated check, respectively. Among the other treatments spinosad, *B.t.k*, *B. bassiana*, *N. rileyi*, *M. anisopliae* and Sl NPV were found to be least effective against *A. biguttula biguttula*, *B. tabaci* and *A. craccivora* on sunflower. The results regarding the efficacy of spinosad against *S. litura* and sucking pests in sunflower are in agreement with Sudhakara Reddy *et al.* (2004) and Sparks *et al.* (1998).

Spinosad 45 SC (0.015%) treated crop provided significantly highest yield of 1658 kg/ha followed by B.t.k 0.2% (1491 kg/ha), Neemazal 0.03% (1438 kg/ha) against untreated check (949 kg/ha). Significantly higher yields compared to untreated check were recorded in all the treatments.

Table 1 Reduction in mean intensity of major insect pests of sunflower against untreated check

Treatment	Mean percent reduction of population over untreated check				Seed yield (kg/ha)
	S. litura	*A. biguttula biguttula*	*B. tabaci*	*A. craccivora*	
Nimbecidine (300ppm) 1%	22.35 (28.21)	28.11 (32.02)	26.86 (31.21)	26.09 (30.72)	1287
Nivaar(1500ppm) 0.2%	25.55 (30.36)	32.48 (34.74)	32.25 (34.60)	29.96 (33.18)	1380
Neemazal T/S (10000ppm)0.03%	28.83 (32.47)	38.20 (38.17)	37.09 (37.51)	36.83 (37.36)	1438
SFRE 5%	25.06 (30.04)	30.65 (33.61)	27.63 (31.71)	25.37 (30.24)	1200
Nomuraea rileyi 1x10^{8}	32.59 (34.81)	9.55 (18.00)	8.77 (17.22)	9.59 (18.04)	1176
Beauveria bassiana 1x10^{13} conidia/ml	29.60 (32.80)	10.56 (18.96)	10.53 (18.93)	9.93 (18.37)	1104
Ha NPV/Sl NPV 250 LE/ha	34.92 (36.22)	4.41 (12.13)	4.03 (11.58)	4.84 (12.71)	1138
Metarrihizium anisopliae 1x10^{13} conidia/ml	29.16 (32.68)	8.96 (17.42)	7.83 (16.25)	6.87 (15.19)	1067
Bacillus thuringiensis Var kurstaki 0.2%	36.50 (37.17)	13.20 (21.30)	11.99 (20.25)	11.42 (19.75)	1491
Spinosad 45SC 0.015	51.02 (45.58)	19.95 (26.53)	16.53 (23.98)	17.59 (24.79)	1658
Untreated check	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	940'
SEm±	0.15	0.16	0.16	0.17	18.2
CD (P=0.05)	0.45	0.48	0.49	0.53	52.5

SFRE: Sweet Flag Rhizome Extract; **DAS: Days after spraying**; Values in parenthesis are angular transformed values

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Short communication

Savitri (SWB 32-10-1) : High oil and high yield sesame, *Sesamum indicum* L. variety

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Abstract

Savitri (SWB 32-10-1) high oil and high yield sesame variety released for cultivation by CVRC.

Keywords: Sesame, high oil and seed yield

Sesame (*Sesamum indicum* L.), the queen of oilseed crops is the most ancient oilseed crop domesticated in India more than 5000 years ago (Duhoon *et al.*, 2000). In India, the crop is grown in an area of 1.7 million ha with a production of 0.6 million tonnes and productivity of 363 kg/ha (2006-07). India ranks second in production, next to China with major sesame growing states Rajasthan, Maharashtra, Gujarat, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, West Bengal, Karnataka and Orissa (Hegde, 2009). Though India is the world leader in terms of sesame production and export, the productivity is very low due to poor management and non adoption of new technologies.

West Bengal is the leading state among sesame growing states in the country with highest productivity. Farmers of this state grow sesame mainly after harvest of winter potato during summer season with or without fertilizer application. They prefer sesame due to its drought tolerant nature and short duration that fits well between winter and *kharif* crops. Two varieties Rama (Improved selection 5) and Tilottama (B-67) released before 1990 are predominantly grown. These varieties have less oil content (around 45%) and susceptible to *Macrophomina* stem rot disease. A new variety Savitri (SWB 32-10-1) has been found promising in All India Coordinated trials and released by Central Variety Release Committee in Oct.2008. This article reports the new variety Savitri that holds promise for irrigated production system of the country.

With a view to develop new sesame variety the entry SWB 32-10-1, a selection from local germplasm SWB-32 collected from Sagardighi block of West Bengal was tested in preliminary evaluation Trial at Pulses and Oilseeds Research Station, Berhampore during summer 2004 and 2005. The entry was sent to Project Coordinator's unit, Sesame and Niger, tested under All India Coordinated trial during summer 2006. The results of initial varietal trial (summer) 2006 (Table 1) showed that it performed best among eight locations over India with yield advantage of 32.02, 39.0 and 20.0% over RT-54(NC),TKG-22(NC) and Rama(SC). In the advanced varietal trial (summer) 2007 it registered 13.13, 41.30 and 33.46% yield advantage over RT-54,TKG-22 and Rama. Further the variety recorded 0.82, 6.49 and 6.96% yield advantage over three qualifying varieties (*viz.*, PKDS 64, TKG-353 and PKDS-1) during summer 2006 and 5.76, 9.23 and 12.22% yield advantage over three qualifying varieties during summer 2007.It is to be noted that among the sesame varieties, white-seeded varieties contain more oil than black or brown seeded varieties. The new variety Savitri (SWB 32-10-1) though being non-white seeded variety, contains 51.1% oil. Besides this during storage condition white-seeded varieties are attacked by stored grain pests within few months due to thin seed coat. But the variety Savitri can be safely stored more than three years without attack of stored grain pests.

The morphological features of Savitri and standard check Rama are presented in table 2. It is found that higher number of primary branches/plant, number of capsules/plant, number of seeds/capsule and 100-seed weight resulted in higher seed yield than Rama. This high oil content (51.1%) resulted in higher oil yield/ha (Table 1) of the new variety.

The variety was also tested under farmers' field through front line demonstration trial during summer 2008 and summer 2009. A perusal of the table 3 shows 18.36 and 36.56% yield advantage over two popular varieties Rama and Tilottama during summer 2008 and 2009.

Looking to its consistent performance over different locations and years under All India Coordinated trial, the variety was identified by the varietal identification committee meeting for Sesame and Niger, held in May 2008 for irrigated condition during *rabi*/summer season of the country and also for coastal ecosystem of Zone III.

Table 1 Performance of Savitri (SWB 32-10-1) over checks and other qualifying varieties in All India Coordinated trial (IVTS, 2006 and AVTS 2007)

Variety	IVTS 2006		AVTS 2007			
	Yield (kg/ha)	% increase	Yield (kg/ha)	% increase	Oil yield (kg/ha)	% increase
Savitri (SWB 32-10-1)	738		698		357	
RT-54(NC)	559	+32.02	617	+13.13	319	+11.91
TKG-22 (NC)	531	+39.00	494	+41.30	263	+35.74
Rama (SC)	615	+20.00	523	+33.46	272	+31.25
Other qualifying varieties						
PKDS-64	732	+0.82	660	+5.76	317	+12.62
TKG-353	693	+6.49	639	+9.23	348	+2.59
PKDS-11	690	+6.96	622	+12.22	317	+12.62
Mean		+17.55		+19.18		+17.79

NC = National Check; SC = State check

Table 2 Morphological description of Savitri (SWB 32-10-1)

Descriptor	Genotypes	
	Savitri (SWB 32-10-1)	Rama(SC)
Branching habit	Low branched	Low branched
Stem hairiness	Glabrous	Hairy
Flower colour	Light pink	Purplish white
Days to 50% flowering	36-40	38-40
Days to maturity	84-87	83-86
Plant height(cm)	95-100	100-105
Primary branches/plant	5-6	4-5
Corolla hairiness	Sparsely hairy	Sparsely hairy
Capsules/leaf axil	one	One
Capsule shape	Broad oblong	Narrow oblong
Capsule arrangement	Single opposite	Single opposite
Density of capsule hairiness	Glabrous	Hairy
Capsule length	Medium	Medium
Productive capsules/plant	58-60	47-50
Seeds/capsule	55-60	48-52
1000 seed weight(g)	3.2	2.9
Oil content(%)	51.1	46.0
Seed coat colour	Light brown	brown

SC = State check

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Short communication

Hybrid seed production in sesame, *Sesamum indicum* L. - Prospects

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Abstract

Extent of open pollinated seeds set on male sterile plants and hand emasculated buds was explored to assess the prospects of producing F_1 hybrid seed in sesame (*Sesamum indicum* L.). Seed set on male sterile plants varied from 2.3-5.1% whereas no seed set was observed on emasculated buds. It is inferred that F_1 hybrid seed production in sesame through natural cross pollination can be successful only if (I) insect pollinator population is increased in male sterility based seed production plots and (ii) flower morphology, number/viability of pollen grains is improved so that air borne pollen can affect cross pollination.

Keywords: Open pollinated seed set, male sterility, hand emasculation, F_1 hybrid seed production

Sesame (*Sesamum indicum* L.) is the fifth important oilseed crop of India after soybean, *brassica*, groundnut and sunflower. During 2007-2008 it occupied an area of 1.76 m.ha, which was highest in the world under this crop. Average productivity of sesame in the world (465 kg/ha) is low in comparison to other oilseed crops. In India, the productivity is only 414 kg/ha which is very low as compared to the yield levels (1957 kg/ha) recorded in the research trials (Anonymous, 2004). Relative susceptibility of the crop to biotic and abiotic factors, its cultivation on poor and marginal soils with low or no inputs are the main reasons for low realized yields. Sesame is a high risk crop as its productivity is strongly impacted by the rainfall patterns and other climatic factors. Breeding researches in sesame generally involve enhancement of germplasm base, selection, mutagenesis and recombination breeding for various yield contributing factors. High estimates of heterosis have been reported in hand made experimental F_1 hybrids (Murthy, 1975; Tu, 1993). In India, yield superiority up to 54.3% over the national check variety TKG-22 has been observed in some of the F_1 combinations. Although efforts at producing F_1 hybrid cultivars in sesame are underway for the last 20 years, only limited gains have been reported.

Success of any F_1 hybrid breeding programme depends upon ease of production of hybrid seed on commercial scale. Depending upon flower morphology and nature of the crop, manual or male sterility based seed production techniques can be employed for commercial hybrid seed production. Manual seed production is preferred over other means in a monoecious crop like maize where simple detasseling allows hybrid seed production by cross pollination. This is also facilitated by abundant pollen grain production. In crops like rice, pearl-millet, sorghum, sunflower, *brassica* and wheat where large scale hand emasculation is difficult, use of male sterility is the best option. Cytoplasmic male sterility (CMS) is being used successfully world over to develop F_1 hybrids in all these crops.

Sesame is largely self-pollinating and a small seeded crop with each plant producing thousands of seeds. It belongs to family pedaliaceae; its growth habit is of indeterminate type having large number of flowers with acropetal flowering. The plants continue to grow and produce flowers and capsules over a period of time, depending upon the climate and location. The flowers are borne on short pedicels in the leaf axils either solitary or in a group of two-three. If there is single flower/axil, the lateral primordia develop into nectaries. The sesame flower is bell-shaped, companulate with 2-3 cm long corolla having five stamens inserted at the base. The lower petal has a deep pit and fine hairs are present on the inner side of corolla. Anther dehiscence occurs early in the morning between 5-7 AM affecting self pollination and flowers open after anthesis. The pedicel of an open-flower bends down and the mouth of the corolla face downwards at an angle of 60°. Mode of anthesis (prior to flower opening) in sesame favours self pollination; flower position and morphology prevents out crossing through wind carried pollen. Cross-pollination if any, is affected by insects which visit the flower for big nutritious pollen grains. Sesame pollen grains remain viable for up to 24 hrs. whereas the stigma remains receptive for two days, if not fertilized. Emasculation in sesame is easy. The five anthers can be easily removed by pulling the corolla tube leaving behind bifid stigma. For developing handmade F_1 seed, the young buds to open next morning are emasculated in the afternoon and pollinated in the next morning. In India, hand emasculation has been used to develop F_1 hybrid seed and seed production cost/kg F_1 seed is not very high. In China, hand bred hybrids are commercially grown in some areas. Although ease of manual hybrid seed production and low seed rate (2 kg/ha) makes the cultivation of F_1 hybrids in sesame commercially viable, male sterility is still being sought to further economize on hybrid seed production costs. It has been estimated that one hectare F_1 seed production plot using male sterility can produce sufficient F_1 seed to sow 60-80 ha. In sesame, Tu *et al.* (1995) has explored the use of GMS for producing F_1 hybrids in China. In India, stable CMS lines with 99% pollen sterility have been developed through inter-specific hybridization between *S. malabaricum* and *S. indicum* (Duhoon, 2004). Presence of sufficient outcross seed set is an important pre requisite for commercial hybrid seed production using male sterility. Reports in this regard are scanty and contradictory.

Present study reports on the possibilities of the producing F_1 hybrid seeds in sesame, through open pollination, under north Indian conditions where the crop is grown during July to September-October. Identification of male sterile plants in the M_3 generation of irradiated TC-289 variety allowed us to study outcross seed set on male sterile plants under natural conditions. These plants were allowed to open pollinate and observed critically for out cross seed set during 2006. Data were recorded for productive pods/plant and number of seeds/pod. It was observed that most of the pods formed were false pods (with no seed) and the productive pods had very few seeds (Table 1). Similar results were observed during *kharif*, 2007. Lower number of productive pods (13.7-21.4 %) and lower out cross seed set (2.3-5.1%) reflected on poor out crossing rates.

To confirm these results and to obviate the possibility of impaired female fertility, if any, being a cause of low out cross seed set on male sterile plants, a simple experiment was planned during *kharif* 2007 and 2008 to find out the extent of seed set on emasculated buds. During 2007, preliminary experiment was conducted at three different locations in the sesame field, where flowers from one line were continuously emasculated throughout the flowering period. Observations were recorded on pod formation and seed set on emasculated plants. During *kharif* 2008, the experiment was repeated in a seed production plot. Two genotypes PB Til-1 (white seeded) and GT 10 (black seeded) were raised in paired rows (3m long) alternately, with black seeded genotype on outer side of each plot. Normal plant to plant (15 cm x 30 cm) and row to row distances were maintained. Standard agronomic practices were followed to raise the crop. All the plants of the white seeded genotype PB Til-1 were emasculated daily and observed for pod formation. Productive pods, if any, were to be harvested from these plants at maturity, and evaluated for per cent (as compared to normal) seed set.

Seed set on emasculated buds without artificial pollination can only occur due to pollination affected by airborne pollen as the population of pollinator insects was at the best nominal. No seed set was observed following open pollination on the emasculated buds. The emasculated buds developed into false pods which were devoid of any seed. Extent of cross pollination in sesame at Ludhiana has earlier been observed to be 5-8%. The present observations indicate that what so ever cross pollination occurs is only due to the insects. Dispersal of pollen grains in the air is absent which may be due to sticky nature of the pollen grains, hairy inner side of the corolla or deep pit on the lower petal which captures the pollen grains. Less number of pollen grains per flower and their short life may be the other factors responsible for insufficiency of the air borne pollen to effect pollination on the emasculated open buds. Absence of pollen grains in emasculated buds, a major attractant for insect pollinators, may be a cause of total failure of seed set on emasculated buds. Based on these studies we do not expect the success of hybrid seed production through out crossing on male sterile plants in the areas with limited population of insect pollinators. The sesame crop is attacked by a large number of insects and application of insecticides becomes imperative to avoid yield losses. Regular pesticide application as is done under north India conditions results in much reduced population of insect pollinators which affects extent of out crossing. Varying rates (1-68%) of cross pollination have been reported in various countries depending upon insect activities (Brar and Ahuja, 1979; Yermanos, 1980; Osman, 1985; Musa and Padilla 1991). Wind pollination may have no role to play for facilitating hybrid seed set on male sterile plants. To enhance seed set on male sterile lines it may be better to produce male sterile sources that produce abundant but sterile pollen grains as compared to male sterile lines completely devoid of pollen grains.

Table 1 Extent of productive pod formation and seed set on male sterile plants

Plant	Total pods	Productive pods		Seeds/productive pod	Outcross seed set (%)
		Number	Per cent		
MS-1	156	28	17.9	10	3.6
MS-2	138	20	14.5	8	2.3
MS-3	112	24	21.4	12	5.1
MS-4	131	18	13.7	16	4.4

*Assumption = 50 seeds/pod; total number of seeds inclusive of productive and false pods

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Short communication

YRCH-1, A promising castor hybrid for Tamil Nadu

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Abstract

By conducting 186 trials (national + state) across various locations, a castor hybrid YRCH-1 was identified as a suitable hybrid for rainfed and irrigated ecosystems of Tamil Nadu. It was released by state variety release committee for cultivation in Tamil Nadu.

Keywords: Castor, *Botrytis*, early sowing

Castor is grown both under rainfed and irrigated situations. India is the first country to commercially exploit heterosis by two line hybrid breeding based on indigenous, stable S type pistillate line, VP-1. At present, 14 hybrids and more than 18 varieties are released either at the central or state level.(Anonymous, 2006)

In Tamil Nadu, the choice of the castor hybrid for cultivation is very limited with availability of only few hybrids. Hence there is urgent need to develop and release a high yielding castor hybrid for rainfed and irrigated ecosystem of Tamil Nadu.

The castor hybrid YRCH 1 is tested in station trials, MLT, ART, OFT and ICAR -co-ordinated trial along with popular checks like GCH 4, DCH 177 and TMVCH 1.Overall, the hybrid has been tested in 186 trials across various locations.

The castor hybrid YRCH 1 recorded seed yield of 1861 kg/ha which is 27% higher than the national check GCH 4. Duration-wise, it is 15 days earlier than TMVCH 1 and 30 days earlier than GCH 4. Because of its earliness escapes *Botrytis* in early sown conditions during *kharif*.

In AICRP (Castor) coordinated trials also the new hybrid YRCH 1 recorded highest seed yield of 2082 kg/ha which is numerically superior than the national check GCH 4 (Table 1).

Farmers participatory varietal selection: Success of new crop varieties depends upon quick adoption. Often it is rather slow in marginal environments .Many times the improved varieties from the researcher fail due to the reason that farmers perception change over time. Varieties /hybrids selected from such participatory varietal selection (PVS) trials are likely to be broadly accepted and in turn acceptable to farmers.

Table 1 All India trials conducted under coordinated research project on castor at various research centres across India

Hybrids	Rainfed (Mean of 8 trials) (kg/ha)	Irrigated (Mean of 8 trials) (kg/ha)	Mean of 16 trials (kg/ha)
YRCH 1	1546	2618	2082
GCH 4	1602	2439	2021

In addition to evaluation under station trials, MLT, ART and national trials the new hybrid is subjected to PVS under farmers' field for 3 years (2006-2008).

The hybrids were coded and the farmers were asked to make their own evaluation and select the hybrids of their choice for cultivation. At all the locations except very few farmers, all others opted for the new hybrid YRCH 1 as their choice. The farmers observed earliness, compact highly pistillate productive spike, high branching, lesser time lapse between any two order of spike, compact and short plant type and escape from *Botrytis* in early sown conditions and higher seed yield as the reasons for selecting YRCH 1 as the hybrid of their choice.

Table 2 Summary of evaluation in farmers' field (OFT) (Seed yield kg/ha)

Hybrid	2006 Mean of 10 trials (kg/ha)	2007 Mean of 40 trials (kg/ha)	2008 Mean of 50 trials (kg/ha)	Weighted mean (100 trials) (kg/ha)
YRCH 1	2225	1986	1905	1969
GCH4	1750	1509	1390	1473
TMVCH1	1650	1421	1326	1396

Reaction to major disease under field and controlled conditions: Because of its earliness, escapes *Botrytis* in early sown conditions during *kharif*. In the field for *botrytis* incidence it recorded the score of 5 in the 0-9 scale with only 11 to 25% of capsule affected under normal epiphytotic conditions. Where as the checks GCH 4 and TMVCH 1 have recorded the score of 9 in the scale with more than 50% of affected capsule. The botrytis incidence is less, may be due to disease escape because of earliness, in *kharif* season.

Reaction to major pests (under field and controlled conditions including storage pests):

Leaf hopper: For the incidence of leaf hopper the hybrid has recorded the score of 2 in 0-11 scale (Hopper burn 11-25%). The hybrid is resistant to jassids because of triple bloom.

White fly: The hybrid has recorded the score of 1 in the 0-5 scale (1 to 50 pupae/3 leaves/plants during peak infestation level.

Capsule borer: Moderately tolerant to capsule borer with the capsule borer incidence of less than 20% during peak infestation level.

Salient features of castor hybrid YRCH-1:

- Average yield 1861 kg/ha under rainfed ecosystem and oil content of 49%.
- Early duration of 150-160 days (15 days earlier than TMVCH 1 and 30 days earlier than GCH 4).
- Suitable for rainfed and areas of limited irrigation potential because of its short duration.
- Less time lag between any two order of spike, hence more number of spike is produced in short period.
- Compact plant type suitable for intercropping system also.

The castor hybrid YRCH 1 has been released for cultivation for Tamil Nadu by the state variety release committee in 2009.

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Short communication

Critical limits of boron in castor, *Ricinus communis* L. leaves and sandy loam soils

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Abstract

A field experiment was conducted in a red sandy-loam (Alfisol) soil to establish boron critical limit in castor (cv. DCH-177). Recently matured leaf (RML) samples positioned on the main stem from the top were collected at 65 and 90 days after sowing and analysed for boron content. Critical boron limits for castor leaves at 65 and 90 DAS were found to be 70 and 65 mg/kg, respectively and the hot water soluble boron critical limit for Alfisol was 0.08 mg/kg.

Keywords: Castor, critical limit, boron, leaves, Alfisol

Castor (*Ricinus communis* L.) is one of the important industrial oilseed crops cultivated in semi-arid region of Andhra Pradesh under rainfed conditions in red 'chalka' soil (Alfisol). Amongst the seven micronutrients essential for crop growth and development, boron (B) plays vital role in oilseed production. Boron essentiality in oilseed crops has been well established (Agarwala *et al.*, 1981; Asad *et al.*, 2002). Further, in several oilseed growing soils of semi arid region, deficiencies of B along with the other nutrients are widespread (William Dar, 2004). Boron studies in major oilseed crops were reviewed by Murthy (2006). However, information on the effect of boron in castor is scanty. Hence, an investigation was made to establish boron critical limit in castor leaves and in Alfisol.

A field experiment was conducted with castor hybrid DCH-177 as test crop during *kharif* 2007 to determine the critical boron level in red sandy-loam (Alfisol) soil. The physico-chemical characteristics of the soil *viz.* pH, electrical conductivity and organic carbon found to be 7.2, 0.2 dS/m, 0.3%, respectively. The available N, P_2O_5 and K_2O were 180, 10 and 210 kg/ha, respectively. The initial hot water soluble boron (HWS-B) content in the soil was very low i.e., 0.02 mg/kg. The experiment was laid in randomised block design with three replications. Graded levels of B *viz.*, 0, 0.5, 1.0, 1.5, 2.0, 2.5 and 3 kg/ha were applied through Borax. Recommended dose of N and P (40 kg/ha each) was applied. Recently matured leaf (RML) samples of the main stem from the top were collected at 65 and 90 days after sowing (DAS) and analysed for B content. Soil available B was estimated at initial stage and 30 days after the basal application of B, as per the standard procedures (Jackson, 1973). Boron content in the leaves was estimated as per the procedure described by Wolf (1971). Scatter diagrams were drawn to establish soil and castor leaf critical B limits.

The B content in the recently matured leaves varied from 39.0 to 139.0 mg/kg at 65th day and 37.8 to 84.8 mg/kg at 90th day amongst the B treatments. In young leaf of mustard (52 DAS) the established deficiency, sufficiency and toxicity limits of B were 10-25, 25-70 and >70 mg/kg, respectively (Patel *et al.*, 2003). Whereas the sufficiency and toxicity levels of B for groundnut and sunflower were recorded 29-125 and 218, 29-125 and >160 mg/kg, respectively (Sakal and Singh, 1995). In the present investigation, the B content observed in castor leaves is in accordance with the reported information in other oilseed crops. The scattered diagrams drawn for HWS-B vs. castor leaf B content at 65 and 90 days have shown that the critical leaf B content at 65th and 90th day was 70 (Fig.1) and 65 mg/kg (Fig.2), respectively.

Hot water soluble B content in the soil at 30th day varied widely from 0.04 to 0.12 mg/kg amongst the B treatments. Rattan and Goswami (2002) reported that the soils may have critical limits of B in the range 0.1 to 1.0 mg/kg depending on the soil type and oilseed crop grown. In this study, the critical limit of HWS-B content of the red soil (Alfisol) was found to be 0.08 mg/kg (Fig.1 and 2). A critical HWS-B value of 0.1 mg/kg for red soil with castor variety DCS-9 was also reported by Murthy and Padmavathi (2009).

From the present investigation, it can be concluded that the critical B concentration for the separation of B responsive soil (Alfisol) from non responsive soils is 0.08 mg/kg to maintain the critical castor leaf B content of 65 to 70 mg/kg.

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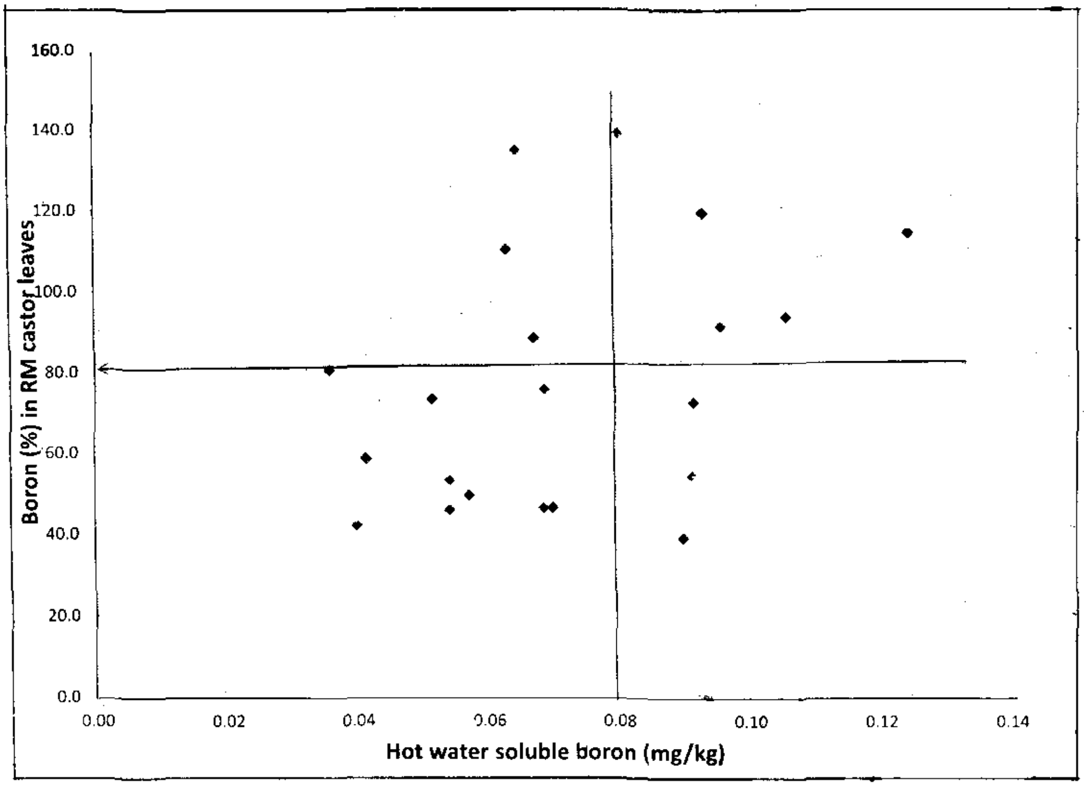

Fig. 1. Critical limits of boron in recently matured castor leaves and soil at 65 DAS

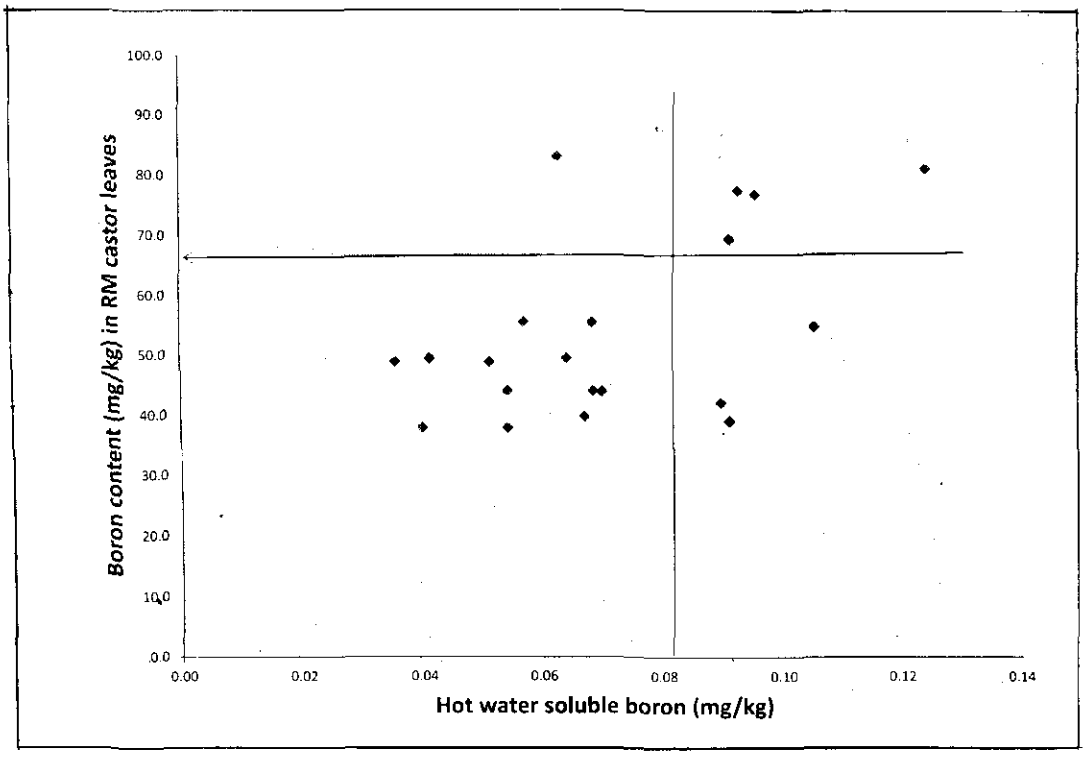

Fig. 2. Critical limits of boron in recently matured castor leaves (DCH-177) and soil at 90 DAS

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Short communication

Variability for water use efficiency traits and drought tolerance in castor, *Ricinus communis* L. germplasm lines

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Abstract

An experiment was conducted during *rabi* 2005-06 to examine the genotypic differences in water use efficiency (WUE) traits and to identify lines with drought tolerance. Eleven germplasm lines were sown and stress was imposed by withholding irrigation from 45DAS and extended till 120 DAS. Plant height, leaf number and tertiary branch production was reduced significantly with stress. SCMR was significantly more in stress at 55 DAS. Specific leaf area (SLA) did not differ significantly in control and stress. Strong negative correlation of SCMR with SLA is seen (>-0.90.) both in control and stress treatments. Genotype RG297 showed high SCMR, low SLA, and high total drymatter (TDM) both in control and stress treatments. This genotype also showed higher seed yield and harvest index (HI) in stress with less percent reduction in seed yield compared to control and with low drought susceptibility index (DSI) values.

Keywords: Drought tolerance, WUE, germplasm, drought susceptibility index (DSI)

Under drought conditions, yield is determined by water use efficiency (WUE). This character showed significant genetic variability and also has heritability (Wright *et al.*, 1988; Farquhar *et al.*, 1989). Traits like specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR) are alternate approaches for measuring WUE. The relationship between SCMR and transpiration efficiency (TE) was established by Sheshashayee *et al.* (2001) in groundnut. Nageshwar Rao *et al.* (2001) has demonstrated the uses of SPAD as a selection tool for SLA and specific leaf nitrogen (SLN) suggesting that SCMR could be used as a nondestructive and indirect measure of TE in groundnut. Castor (*Ricinus communis* L.) is grown in Andhra Pradesh mainly as rainfed crop in marginal and submarginal shallow soils with low inputs. The crop experiences water stress at different stages of crop growth depending on rainfall pattern during the season which results in reduced yields. As castor was considered drought tolerant, no importance was given to further improve its tolerance to drought aiming at increasing the possibility of stabilizing the yield under stress environment. Hence, an experiment was conducted to examine the genotypic differences in WUE traits and to identify lines with drought tolerance which can be used in breeding programmes.

Eleven germplasm lines which showed pest, disease and temperature tolerance at Directorate of Oilseeds Research (DOR) were sown during *rabi* 2005-06 and stress was to be imposed from 30-90 days after sowing (DAS) but as there was rainfall during imposition of treatment, stress was imposed by withholding irrigation from 45 DAS and extended till 120 DAS. Total rainfall received during crop growth was 44.2 mm. Control plants received 9 irrigations and stressed plants were given 4 irrigations during the crop growth. Observations on SCMR and SLA were recorded on 4th fully expanded leaf from top at 55 DAS and 90 DAS. Correlation coefficients between these two traits were computed. Data on various growth characters were recorded before relieving stress (120DAS) and yield and yield components were recorded. Drought susceptibility index (DSI) was also computed (Fischer and Maurer, 1978). The data on different growth characters were recorded before relieving stress at 120 DAS (Table 1). Plant height, leaf number and tertiary branch production was reduced significantly with stress. RG 247, RG 297 showed less percent reduction in plant height, leaf number and tertiary branch production with stress.

SCMR was significantly more in stress at 55 DAS. SLA did not differ significantly in control and stress (Table 1). But genotypic differences were significant both for SCMR and SLA at 55 and 90 DAS. Among different genotypes, RG 297 recorded significantly higher SCMR in both control and stress treatments at 55, 90 DAS. RG 297, RG 1449 recorded significantly higher SCMR in stress compared to control at 55 DAS. Significantly lower SLA were recorded in RG 297 and RG 242 in control and RG 242, RG 297, RG 707 and RG 1449 in stress at 55 DAS. Whereas, at 90 DAS, RG 1449, RG 297, RG 707 in control and RG 297, RG 1624 in stress recorded less SLA. RG 297 showed consistently high SCMR and low SLA at two stages of sampling. Strong negative correlation of SCMR with SLA is seen (>-0.90) at two stages of observation both in control and stress treatments (Fig. 1 and 2.). Similar relationships were observed in groundnut by Nageshwar Rao and Wright (1994).

Table 1 Effect of water stress on growth characters, SCMR and SLA in castor

Genotype	Plant height (cm/plant)		Leaf number/plant		Secondary branches/plant		Tertiary branches/plant		SPAD chlorophyll meter reading (SCMR)				Specific leaf area (SLA) dm²/g			
									55 DAS		90 DAS		55 DAS		90 DAS	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
RG298	46.1	38.7	63	47	5	3	4	2	53.6	54.9	59.6	59.2	2.004	1.960	4.414	1.552
RG661	42.7	32.1	25	13	3	3	2	1	55.8	59.5	51.4	56.9	1.858	1.634	2.076	1.717
RG707	47.8	42.7	28	24	3	3	3	1	55.8	62.6	60.6	50.3	1.748	1.371	1.432	1.930
RG17	25.6	27.3	29	36	3	4	3	2	53.2	53.1	58.5	50.7	1.943	2.044	1.599	1.938
RG247	43.0	42.6	24	32	2	2	2	2	56.4	57.7	55.5	55.5	1.726	1.802	1.826	1.820
RG297	54.5	48.0	28	29	4	3	2	2	60.1	61.2	60.6	61.3	1.442	1.471	1.414	1.346
RG1922	84.9	38.8	25	18	3	2	2	0	58.7	59.1	58.8	54.8	1.518	1.516	1.693	1.939
RG1449	85.5	53.9	41	23	5	3	2	2	53.6	62.2	64.1	64.5	1.987	1.371	1.342	1.343
RG1608	75.1	60.0	22	22	3	2	1	1	55.3	55.9	58.1	60.4	1.887	1.872	1.857	1.463
RG1624	76.3	57.6	23	16	2	2	2	0	55.0	59.7	59.0	60.5	1.844	1.565	1.510	1.387
RG242	48.7	32.5	29	21	4	3	2	2	58.5	62.3	51.9	59.2	1.505	1.344	2.025	1.505
Mean	57.3	43.1	31	25	3	3	2	1	56.0	58.9	58.0	57.6	1.769	1.670	1.654	1.630
CD (P=0.05)																
Treatments	2.3		0.6		0.3		0.4		0.9		NS		NS		NS	
Genotypes	3.7		3.6		0.7		0.4		2.0		1.2		0.1		0.1	
Interaction	5.3		5.1		1.0		0.5		2.8		1.7		0.2		0.1	
CV (%)	4.4		1.9		10.4		20.1		5.5		6.1		13.4		8.5	

Table 2 Genotypic differences in total drymatter, total seed yield, harvest index and drought susceptibility index in castor in response to water stress

Genotype	Total drymatter (g/plant)		Total seed yield (g/plant)		Harvest index (%)		% reduction in seed yield	Drought susceptibility index
	Control	Stress	Control	Stress	Control	Stress		
RG298	206	150	59.2	18.7	0.29	0.12	68.4	1.60
RG661	192	112	50.0	27.9	0.29	0.26	44.2	1.04
RG707	249	136	68.6	38.0	0.27	0.28	44.6	1.05
RG17	85	93	28.0	15.2	0.33	0.16	45.7	1.07
RG247	192	177	75.3	43.0	0.39	0.26	42.9	1.01
RG297	228	177	56.8	55.5	0.25	0.32	2.3	0.05
RG1922	175	99	32.8	25.1	0.20	0.25	23.5	0.55
RG1449	219	118	61.6	29.9	0.29	0.25	51.5	1.21
RG1608	153	139	14.3	10.7	0.10	0.08	25.2	0.59
RG1624	177	146	40.2	16.2	0.26	0.11	59.7	1.40
RG242	208	113	59.4	33.1	0.29	0.30	44.3	1.04
Mean	190	133	49.7	28.5	0.27	0.22		
CD (P=0.05)								
Treatments	29.6		9.3		0.03			
Genotypes	37.0		7.7		0.06			
Interaction	52.3		10.9		0.09			
CV (%)	17.3		22.5		10.6			

Table 3 Castor germplasm lines with high WUE traits

Treatment	High SPAD chlorophyll meter reading	Low specific leaf area	High total drymatter	High seed yield	High harvest index
Control	RG 247, 297, 1922, 242	RG 297, 1922, 242	RG 298,707, 297,1449,242	RG 707,247, 1449	RG 247,17
Stress	RG 61, 707, 247, 297,1922,1449, 1624,242	RG 707,1449, 242	RG 298,247, 297	RG 707,247, 297, 242	RG 297, 242

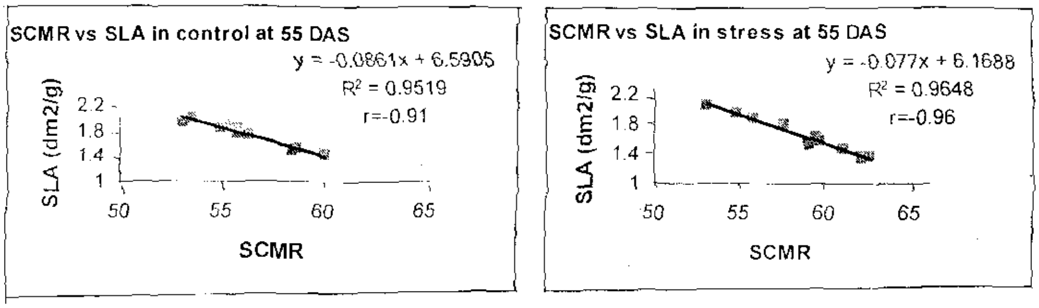

Fig. 1. Effect of water stress on relationship of SCMR vs SLA at 55 DAS

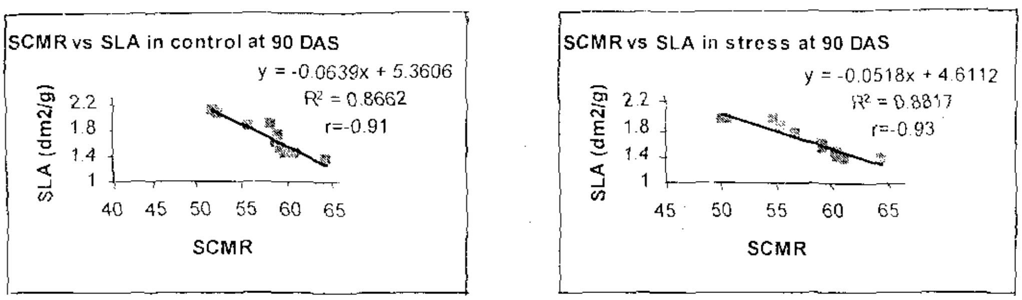

Fig. 2. Effect of water stress on relationship of SCMR vs SLA at 90 DAS

Total drymatter (TDM), seed yield and harvest index (HI) also reduced significantly with stress. Genotypic differences in TDM and seed yield are presented in table 2. RG 17, RG 247, RG 297, RG 298, RG 1608 and RG 1624 recorded <30% reduction in total drymatter compared to control. RG 297 recorded significantly higher seed yield (55.5g/plant) in stress and showed the least reduction in seed yield (2.3%) compared to control. RG 1922 followed by RG 1608 also showed less percent reduction in seed yield (<30%) compared to control and also showed least DSI values compared to other genotypes. Castor germplasm lines that showed better WUE traits are presented in table 3. Significant growth and yield reduction with stress in castor was also recorded in our earlier studies on germplasm screening for drought tolerance (Lakshmamma and Lakshmi Prayaga, 2006).

SCMR and SLA showed strong negative correlation both in control and stress treatments. Among the genotypes studied, RG 297 showed high SCMR, low SLA, and high TDM both in control and stress treatments. The genotype also recorded higher seed yield and HI in stress condition with less percent reduction in seed yield compared to control and with low DSI values.

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Short communication

Genetic divergence in safflower, *Carthamus tinctorius* L.

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Abstract

Genetic divergence among 64 germplasm accessions of safflower assessed using Mahalanobis D^2 values indicated considerable diversity in the material studied. The accessions were grouped into nine clusters. The pattern of distribution of genotypes into various clusters was at random revealing that geographical and genetic diversity were not related. Maximum inter-cluster distance was observed between cluster VIII and cluster II, while the closest proximity was noticed between cluster I and cluster II. Among the eight characters evaluated, days to 50% flowering, number of effective capitula/plant, plant height and number of filled seeds in main capitulum together accounted for more than 90% of the total divergence.

Keywords: Safflower, D^2 statistics, genetic divergence

Safflower (*Carthamus tinctorius* L.) originated in Middle East Asia. It has been under cultivation in India for a long time as an important source of edible oil and is also used in the manufacture of red (carthamin) and yellow dye (Knowles, 1989). A logical way to start any breeding programme is to survey the variation present in the germplasm. Precise information on the nature and degree of genetic divergence would help the plant breeder in selecting potential accessions for utilization in breeding programmes.

The material for the present investigation comprised of 64 germplasm accessions received from the Germplasm Management Unit (GMU) of Safflower, Directorate of Oilseeds Research (DOR), Hyderabad. The study included 21 exotic accessions from 9 countries, 39 Indian accessions and 4 cultivated varieties. The experiment was laid out in simple lattice (8x8) design with two replications during *rabi* 2005-06 at College Farm, College of Agriculture, Acharya N.G. Ranga Agricultural University, Hyderabad. Each genotype was sown in three rows of 2 m length with a spacing of 45 cm x 20 cm. Recommended agronomic practices and prophylactic measures were adopted for raising a good crop.

Data were recorded for 8 economic traits on 10 competitive plants over two replications and mean values were used for analysis. Analysis for genetic divergence using Mahalanobis D^2 statistic was carried out as described by Rao (1952). On the basis of the magnitude of the D^2 values, the investigated genotypes were grouped into different clusters by employing Tocher's method as outlined by Rao (1952).

The 64 germplasm accessions were grouped into 9 clusters (Table 1). Clusters II and III were the largest consisting of 13 accessions each while clusters VIII and IX were the smallest with 3 genotypes each. As already reported by researchers on safflower (Patil *et al.*, 1984, 1991; Patel *et al.*, 1989; Diwakar *et al.*, 2006), genetic diversity was not associated with geographical origin in the present evaluation and the pattern of distribution of genotypes from various geographical regions into different clusters was at random. This tendency of genotypes to occur in clusters irrespective of geographical boundaries demonstrated that geographical isolation alone was not responsible for genetic diversity. Murthy and Arunachalam (1968) have suggested that genetic drift and forces of natural selection over diverse environmental conditions within a country could cause considerable diversity compared to geographical isolation.

Maximum inter-cluster distance was observed between cluster VIII and cluster II (D^2 2761.41), while the closest proximity was noticed between cluster I and cluster II (D^2 273.13) (Table 2). The maximum intra-cluster distance was observed in cluster V (687.07) and this might have been due to gene exchange or selection practised among the genotypes for diverse characters. Cluster I displayed the least intra-cluster distance (93.33) revealing the similarity of the 7 genotypes within the cluster.

Presence of variability in the 64 germplasm accessions was also reflected in the cluster means for the 8 traits evaluated (Table 3). The maximum cluster means were revealed by cluster VIII for diameter of main capitula, number of filled seeds, oil content and seed yield/plant and the genotypes within this cluster can be utilized for safflower improvement through further selection for desirable traits.

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Analysis for estimating the contribution of various characters towards the expression of genetic divergence (Table 4) indicated that days to 50% flowering (36.56%), number of effective capitula/plant (27.83%), plant height (17.36%) and number of filled seeds in main capitulum (10.76%) contributed maximum towards genetic divergence in this collection. Since they accounted for more than 90% of total divergence in the material, these basic attributes of the plant architecture need greater attention. Similar results were reported by Patil *et al.* (1991) who observed that plant height, days to flowering and number of filled seeds/capitulum contributed more towards genetic diversity in the 30 safflower genotypes evaluated by them.

Accessions from the two most divergent clusters *viz.*, GMU 4069, 6940, 6942 from cluster VIII and the 13 accessions in cluster II were identified as potential parents in future endeavours for improvement of safflower. Emphasis needs to be given to days to 50% flowering, number of effective capitula/plant, plant height and number of filled seeds in main capitulum during selection to improve seed yield in safflower.

Table 1 Distribution of 64 genotypes of safflower in different clusters

Cluster	No. of genotypes	Genotypes/check varieties
I	7	GMU 57, 1872, 2142, 2149, 3118, 3454, 4716
II	13	GMU 1181, 1880, 2080, 2092, 2444, 2635, 2891, 3097, 3104, 3162, 3382, 3427, 3456
III	13	GMU 753, 862, 1118, 2091, 2153, 3144, 3154, 3185, 3906, 4087, 4279, 4803, 6958
IV	8	GMU 2680, 2843, 4091, 5801, 6970, Manjira, JSI-7, A-1
V	4	GMU 763, 3138, 6939, NARI-6
VI	9	GMU 3258, 3423, 4045, 4056, 4061, 4063, 4122, 4760, 6947
VII	4	GMU 2939, 4808, 4821, 4842
VIII	3	GMU 4069, 6940, 6942
IX	3	GMU 4845, 5775, 6946

Table 2 Average intra (bold) and inter Euclidean cluster distances

Cluster	I	II	III	IV	V	VI	VII	VIII	IX
I	**93.33**	275.13	467.76	955.40	2321.51	1643.37	1540.89	2596.30	2280.32
II		**158.36**	631.24	618.13	1799.85	1651.23	1154.53	2761.41	2139.09
III			**311.82**	1042.07	1685.02	850.55	1031.95	1449.27	1634.15
IV				**263.66**	943.38	1704.69	1005.75	2191.72	1073.29
V					**687.07**	1474.50	897.17	1675.29	1020.85
VI						**292.35**	604.46	752.95	1378.28
VII							**291.49**	1442.75	1291.48
VIII								**256.69**	853.16
IX									**282.87**

Table 3 Cluster means for evaluated traits of 64 safflower accessions

Cluster	Days to 50% flowering	Plant height (cm)	No. of effective capitula/plant	Diameter of main capitulum (mm)	No. of filled seeds in main capitulum	100-seed weight (g)	Oil content (%)	Seed yield/plant (g)
I	81.46	63.75	24.19	21.39	32.72	3.90	19.75	31.3
II	81.62	65.96	26.35	23.26	22.62	4.77	21.85	23.4
III	85.56	79.99	21.63	25.44	34.09	4.29	23.82	36.6
IV	81.19	76.30	39.50	22.60	24.25	4.43	22.72	22.5
V	85.81	103.04	33.82	23.31	21.90	4.15	23.37	16.4
VI	97.06	89.83	22.57	25.67	31.96	4.67	24.86	30.9
VII	94.25	85.75	27.21	25.17	19.99	5.29	17.27	16.7
VIII	95.33	100.39	32.94	29.49	43.38	3.94	28.64	52.1
IX	89.17	89.05	49.11	24.61	37.62	4.17	21.53	43.7
Mean	86.56	79.47	28.16	24.23	29.04	4.45	22.66	29.3

Table 4 Contribution of different characters towards genetic divergence in 64 genotypes of safflower

Source	No. of times ranked first	Per cent contribution towards divergence
Days to 50% flowering	737	36.56
Plant height (cm)	350	17.36
No. of effective capitula/plant	561	27.83
Diameter of main capitulum (mm)	5	0.25
No. of filled seeds in main capitulum	217	10.76
100-seed weight (g)	10	0.50
Oil content (%)	9	0.45
Seed yield/plant (g)	127	6.30

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Short communication

Evaluation of linseed, *Linum usitatissimum* L. germplasm for biochemical traits

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Abstract

Twenty nine germplasm accessions of linseed, *Linum usitatissimum* were evaluated for morphological and bio-chemical characteristics. Wide diversity occurred in germplasm for the characteristics under study. Eleven accessions had more than 50% linolenic acid being highest of 54.6% in IC-345466.

Keywords: Linseed, germplasm, biochemical characters

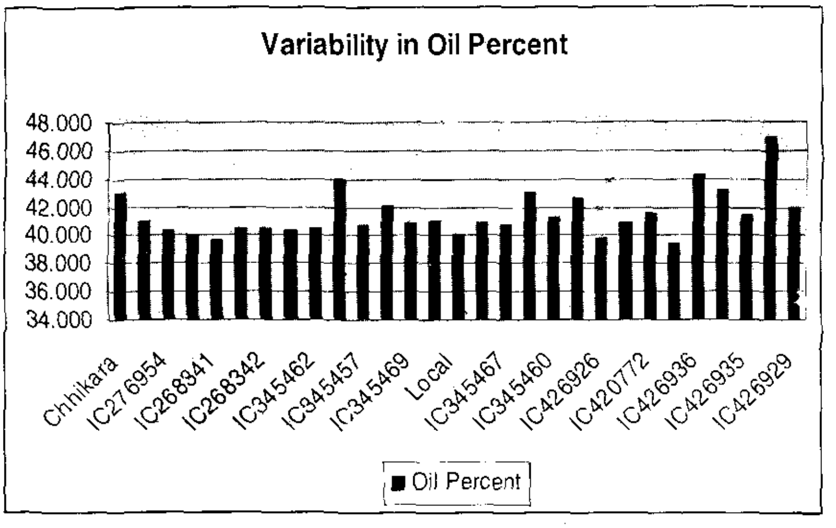
Linseed (*Linum usitatissimum* L.) belonging to family Linaceae is one of the important oil and fibre yielding crops of India and generally grown on marginal lands. It has nutritional, medicinal and industrial uses. Because of the high linolenic acid content in seed oil, it is used as drying oil in the paint and varnish industry (Mc Hughen, 1992). The residue cake remaining after oil extraction contains high protein and is used as rich proteinaceous feed for the livestock and as organic manure. Fibers obtained from the stem are of good quality and are utilized for manufacture of rough textiles. Linseed oil is also utilized in the process of cementing of roads in the USA (Weiss, 2000). A coating prevents destructive water and salts from penetrating concrete. India is the third largest producer of linseed oil in the world. In India, Madhya Pradesh leads in yield and acreage (Radhamani *et al.*, 2006) followed by Uttar Pradesh, Maharashtra, Chhattisgarh, Bihar, Jharkhand, Karnataka and West Bengal. Linseed is an erect annual, 60-120 cm high. Flowers are small, blue, bluish violet or white, in terminal panicle; fruit capsules, with five cells, each containing 2 seeds; seeds yellowish or blackish brown, small, flattened, and oval with smooth shining coat.

The present study was undertaken to study the performance of linseed germplasm for some quality traits of seed oil, protein and fatty acid profile in 29 indigenous linseed accessions. Oleic to linoleic acid ratio and linolenic acid of the oils for accessions was established for the selection of different types of material for use in specific sector. The promising accessions were identified which will prove to be an important genepool for utilization in the breeding programmes. Promising accessions of linseed with total protein content of more than 26% and of total oil content between 43 and 49% and more than 50% linolenic acid content in seed oil were screened for utilization in industrial purposes. Relationships among the quality and agro-morphological traits were established.

A total number of 29 germplasm collections augmented through exploration activities from Bihar, Uttar Pradesh, Himachal Pradesh, Uttaranchal and Jharkhand states in India were grown during *rabi* season of 2004-05 and 2005-2006 at NBPGR Farm, New Delhi. Germplasm was grown in three rows of 3 m row length with 45 cm x15 cm row to row spacing, under augmented block design with two checks *viz.*, Garima (IC426930) and Kiran (IC426925). Three rows of each accession were planted with recommended basal dose of fertilizers following normal cultural practices and plant protection measures. Germplasm was evaluated for different agro-morphological traits *viz.*, plant height (cm), number of primary branches/plant, number of capsules/plant, number of seeds/capsule, 500 seed weight (g), seed yield/plant (g). The observations of each entry were based upon mean values of five randomly selected plants.

Seeds were harvested when attained complete physiological maturity. The mature seeds of linseed were used for protein, oil and fatty acid analysis. Average analysis value for three replicate materials was taken for comparison. For the determination of total oil content, seeds were dried to 4-5% moisture level in oven at 108°C for 16 to 18 hr. The oil content of the seed samples were determined by the a non-destructive method using a Newport NMR analyser (model-4000) after calibrating with pure linseed oil. Recently developed, gas liquid chromatography (GLC) method (Mandal *et al.*, 2002) was followed for the determination of fatty acid profile of the oil. 1.0µl of the methyl ester hexane was injected into a highly polar HP Innowax capillary column of 30m length (inner diameter: 0.32m, film thickness: 0.5 µm, split: 1:80). A Hewlett Packard gas chromatograph, (model 6890) equipped with flame ionization detector (FID) was used. The injector and detector temperatures were 260°C and 275°C respectively. Oven temperature was programmed from 150°C holding at 1min. to 210°C @ of 15°C/min followed by 210°C to 250°C @ of 5°C/min. for 12 min. Peaks of fatty acid methyl esters were identified by comparing their retention time with that of the known standards, run under similar separation conditions. Total nitrogen content of whole seed powder of the samples was determined by conventional Kjeltec 2300 Auto Analyser (Foss Tecator, Sweden). Factor 6.25 was used to convert nitrogen to protein.

The germplasm showed a wide range of variability in number of primary branches/plant (6.87-14.67), length of *main fruiting branch (14.8-61.4), number of capsules on* main fruiting branch (36.2-82.60), number of seeds/capsule (8.2-10.4), 100 seed weight (0.60-0.98g), seed yield/plant (6.0-22.20g). Total oil and protein content of the accessions were found to vary from 46.96 to 39.41% and 27.13 to 17.65% respectively, on whole seed basis (Fig.1). Linseed-meals of the present accessions were found to contain a calculated quantity of 28.4 to 44.94% protein at 3 % oil level. Mean oil content of 41.46% was recorded for the accessions and 23.5 ±1% was the mean protein value of the accessions as well as the Kiran and Garima. Sekhon *et al.* (1973) also observed similar variation from 45.3 to 38.3% oil in 23 linseed germplasm and about 31-46.21% oil content in yellow seeded germplasm was reported by Dubey *et al.* (2006). Oil and fatty acid composition is greatly affected by environmental factors (Schhuster *et al.* (1978), Marquard *et al.* (1978) *and cultural practices (Ford and Zimmerman (1964) and* Yermanos *et al.* (1969).



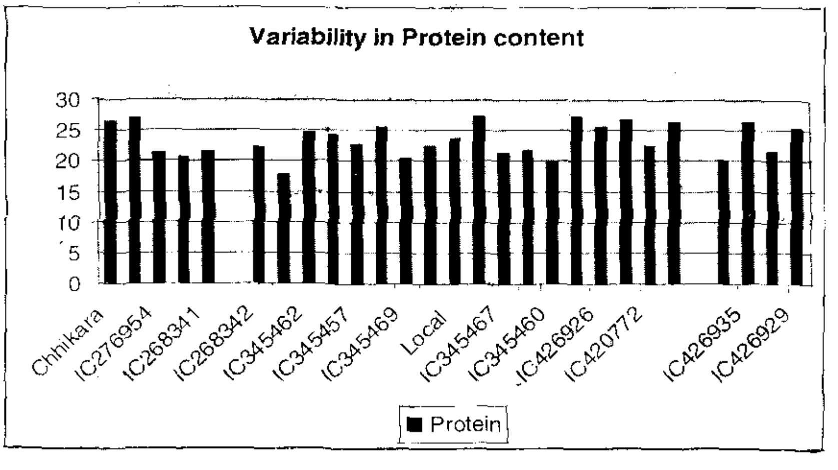


Fig. 1. Linseed germplasm showing variability in oil and protein content

The average palmitic, stearic, oleic, linoleic and linolenic acid values for about 29 accessions studied under the present investigation were 6.28, 6.19, 27.67, 11.24 and 48.29%, respectively. Among these, linolenic acid, the polyunsaturated fatty acid, constitutes about 40.0 to 55.3% of the total fatty acids which is industrially important component of oil. It has been reported that the linoleic acid was up to 54.79% followed by oleic acid which ranged from 22.17 to 41.72% but, Yermanos *et al.* (1966) has reported as high as 63% linolenic acid in wild species of linseed. Oleic and linoleic acid are the other two unsaturated fatty acids considered value rich constituents of any oil for use as food purpose. In the present set of germplasm, the combined percentage of the two fatty acids, the desirable constituents of the oil for food purpose, viz., oleic and linoleic acid varied from 47.27 to 32.08% with mean value of 38.91%. In comparison to this, fatty acids in other edible oils of sunflower, safflower, soybean, rapeseed-mustard and peanut were found to contain mean combine percentage of linoleic, oleic and other monounsaturated fatty acids within the range of 76.8 to 89.8% (Table 3). Variation of 8.09 to 4.53% stearic acid was observed in the present set of germplasm accessions. In comparison to other edible oil, the linseed oil contains high concentration of stearic acid. Because of these adverse oil traits, linseed oil finds very limited application in food purpose. In table 2, comparatively high concentrations of oleic-linoleic acid containing accessions along with other corresponding fatty acids are shown. Significant negative correlation was observed between oleic and linolenic acid content of the oil (r=-0.913). Significant negative correlation was also found between palmitic and linolenic acid (r=-0.465) and between protein and linolenic acid component of the seed oil at 5% level of significance. Seed weight showed positive correlation with seed yield and oil content but negative correlation with protein content (Table 4).

Table 1 Quality and agronomic traits of high linolenic acid (>50%) containing linseed accessions

Accession	Quality traits							Agronomic traits			
	Linolenic acid (%)	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Total oil (%)	Total protein (meal) (%)	Plant height (cm)	No. of primary branches	Seed yield /plant(g)	Seed wt.(g) /500 seeds
IC-276954	53.6	6.2	4.5	25.9	9.7	40.3	35.6	57.8	9.8	12	3.79
IC-275925	52.8	6.4	4.8	26.3	9.5	40.1	34.4	60.6	10.0	10	3.50
IC-268342	52.8	6.5	4.7	26.3	9.5	40.5	37.2	62.2	12.8	16	3.86
IC-345462	51.9	6.9	6.6	21.8	12.6	40.5	41.3	60.5	11.8	14	3.88
IC-345466	54.6	6.0	5.1	23.4	10.7	42.0	44.0	60.0	15.4	16	4.12
IC-345469	55.3	6.2	5.9	19.9	12.5	40.9	34.3	62.9	4.2	12	4.02
IC-345467	54.7	6.4	6.1	20.9	11.7	40.8	45.8	71.3	11.2	14	3.86
IC-345473	52.4	6.2	5.3	21.9	14.1	40.7	35.9	66.6	8.4	14	3.39
IC-345423	54.9	6.4	6.5	19.7	12.3	43.0	38.0	65.5	11.4	12	3.87
IC-345460	54.9	6.6	5.9	20.6	11.8	41.3	33.7	67.5	11.0	10	3.79
IC-426926	50.4	6.0	6.3	25.4	11.7	39.7	42.3	61.9	8.2	10	4.33

Table 2 Quality and agronomic traits of high oleic linoleic acid containing linseed accessions

Accession	Quality traits									Agronomic traits			
	Unsaturated fatty acid (%)				Saturated fatty acid (%)			Total oil (%)	Total protein (%)	Plant height (cm)	No. of primary branches	Seed yield /plant(g)	Seed wt.(g) /500 seeds
	Oleic acid	Linoleic acid	Total	Linolenic acid	Palmitic acid	Stearic acid	Total						
IC-426925	33.86	13.14	47.27	39.98	7.04	5.68	12.72	42.64	27.13	88.7	10	12	3.74
IC-268341	35.46	9.66	45.12	42.38	6.62	5.84	12.46	39.64	21.60	69.8	18.4	6	3.61
IC-376246	35.30	9.60	44.90	41.72	6.68	6.66	13.34	41.06	27.00	65.0	13.8	6	3.61
IC-426935	32.70	9.79	42.49	44.14	7.06	6.45	13.51	41.45	26.14	80.6	7.2	12	4.19
IC-420773	31.99	10.03	42.02	45.42	6.65	5.89	12.54	39.41	26.11	87.66	11.8	22	3.53
Chhikara	30.06	11.7	41.76	43.72	6.67	7.82	14.49	43.03	26.54	64.7	10.4	10	4.93
IC-278340	29.98	11.66	41.64	43.84	6.62	7.86	14.48	40.40	-------	51.2	8.8	10	3.69

Table 3 Fatty acid composition of common edible vegetable oils

Commodity	Saturated fatty acid			Unsaturated fatty acid				Poly unsaturated fatty acids
	Palmitic	Stearic	Total	Oleic	Linoleic	Other	Total	Linolenic
	Percent of total oil							
Mustard	2.44	1.14	3.58	12.10	16.79	56.59	85.38	12.45
Soybean	10.5	3.2	13.7	22.3	54.5	-	76.8	8.3
Sunflower	6.21	3.96	10.17	41.20	48.60	-	89.8	-
Safflower	6.78	3.62	10.40	41.90	47.19	-	89.09	-
Peanut	11.0	2.9	13.3	51.0	13.90	-	81.9	-
Linseed	6.28	6.19	12.47	17.67	11.24	-	38.91	48.29

Table 4 Correlation among quality traits of linseed germplasm

	Palmitic acid	Stearic acid	oleic acid	Linoleic acid	Linolenic acid	Protein
Oil	-0.120	0.151	0.109	0.153	-0.153	0.007
Palmitic acid		0.131	0.233	0.233	-0.465	0.231
Stearic acid			0.336	0.262	-0.503	0.257
Oleic acid				-0.464	-0.913	0.368
Linoleic acid					0.124	-0.100
Protein						-0.439

Promising accessions identified for various morphological traits were IC276954 (10.67), IC420773 (10.2) for number of primary branches, IC278340 (60.43cm), IC276954 (61.87) for dwarf plant height, IC 278340 and IC345467 (9.4) for number of seeds/capsule and IC420773 (49.47) for number of capsules on main fruiting branch. IC345466, IC345469, IC345467 were observed to be good donor for higher oil content. IC-426925 (44.94%), Chhikara (44.25%), IC-376246(43.58%), IC-345467 (43.50%), IC-426928 (42.96%) were identified as promising accessions which yielded more than 43% meal protein. Eleven accessions with more than 50% linolenic acid component have been identified in table 1. IC 345423 (54.9), IC 345460 (54.9), IC 345467 (54.7), IC 345466 (54.6) were higher linolenic acid containing accessions. IC-345467 was also identified as one of the high linolenic acid containing accessions (>54%) and high protein containing meal of 43.50% and may find its inclusion as high industrial oil yielding germplasm accessions in crop improvement programmes.

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Short communication

Scenario of cotton seed (non-conventional oil) in India

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Abstract

With the economic liberalization and globalization sweeping the world, there is a scope for our country to play a leading role in cotton seed production and exports. Against the backdrop of globalization of Indian agriculture and increased demand of cotton seeds, the analysis on cotton seed trade (export and import) scenarios was carried out using data collected from the www.fao.org and analyzed for the overall reference period, 1970-2002 and again during two-sub-periods *viz.*, 1970-1990 (period before trade liberalization) and 1991-2002 (period after trade liberalization) to assess the significance of trade liberalization on the export and import of various products. Results showed that growth rates in area, production and productivity of seed cotton and its products like cotton lint, oil and cake of cotton seed were found positive and significant across all the periods except non-significant for cake of cotton seed during 1986-2003. The share of the export of cotton seed and other products in their respective productions exhibited a gloomy picture, thereby indicating poor export orientation into the international market despite trade openness after 1991. This clearly implies that, these products were less competitive in the international market. The analytical findings revealed that, imports of cotton lint showed significant increasing trend both in terms of quantity (47.84%) and value (40.74%) during the post liberalization period, when compared to pre liberalization periods, where imports showed continuous declining trend. This implies that, with the trade liberalization after 1991, there was free flow of imports into the country without any restrictions so as to meet the domestic demand. Regarding cotton seed and oil of cotton seed, non-significant imports were made for the selected reference periods.

Keywords: Scenario, trade liberalisation, export and import of cotton seed (non-conventional oil)

China is the leading producer of cotton in the world with 30 million bales followed by USA and India with 22 and 14 million bales respectively (2004-2005). India accounts for 20% of world's cotton production. West Africa and Central Asia are much greater markets when compared to other markets in the world.

Compound growth rates (CGR) were worked out to study the growth in area, production and productivity of seed cotton for the overall period (1970-2003) and also during the two subperiod's *viz.*, 1970-1985 and 1986-2003. Similarly, growth rates were again computed for different cotton products like cotton lint, oil and cake of cotton seed pertaining to their production in the country for the periods mentioned above.

The percentage share of export of cotton seed and its products in their respective productions was studied as it highlights their export orientation in the international market. The selected export period 1970-2002 was divided into two sub-periods *viz.*, 1970-1990 (pre-liberalization period) and 1991-2002 (post liberalization period). However, the average share of exports in total production was worked out only for the periods when the exports were regular. Hence, different periods were selected for the selected commodity/products depending upon their regularity. The export-import scenario of cotton was also studied by analyzing the growth of exports-imports both in terms of quantity and value using *www.fao.org* data for the selected reference periods.

It is evident from the table 1 that cotton had shown significant (at 1% level) positive growth rates with respect to area (0.40%), production (2.09%) and productivity (1.68%) levels (Hegde, 2007) during the overall reference period (1970-2003).

Table 1 Growth (%) of area, production and productivity of seed cotton during the selected reference periods in India

Period	CGR		
	Area	Production	Productivity
1970-1985	0.11 NS	1.45**	1.34**
1986-2003	1.43**	2.19**	0.75 NS
1970-2003	0.40**	2.09**	1.68**

** = Significant at 1% level; NS = Non-significant
Raw data source: www.fao.org

To be more precise, the productivity growth exerted more *influence on the production when compared to growth in* area during the reference period. A comparative analysis among the selected two sub-periods revealed that, in the sub-period I (1970-1985), growth in productivity exerted more influence when compared to area in increasing the production and in sub-period II (1986-2003), growth in area exerted more influence than productivity.

Similarly, growth rates were again computed for different cotton products like cotton lint, oil and cake of cotton seed pertaining to their production in the country during the selected reference period and the analytical findings are presented in table 2.

Table 2 Growth (%) of production of cotton products during the selected reference periods in India

Product	Period	CGR
Cotton lint	1970-85	1. 44 **
	1986-03	2.21 **
	1970-03	2.09**
Oil of cotton seed	1970-85	6.75**
	1986-03	1.74*
	1970-03	3.47**
Cake of cotton seed	1970-85	6.73 **
	1986-03	1. 73NS
	1970-03	3.71 **

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

NS = Non-significant, Raw data source: www.fao.org

It is evident from the table 2 that cotton products showed significant (at 1% level) positive growth rates with respect to production during the overall reference period (1970-2003). During the selected sub-periods also, similar growth trends were observed regarding the production of cotton products except for cake of cotton seed during 1986-2003, where the production growth rate turned out to be non significant.

The percentage share of export of cotton seed and its products in their respective production was studied as it highlights their export orientation in the international market. The average share of exports in total production was worked out only for the periods when the exports were regular. Hence, different periods were selected for the selected commodity/products depending upon their regularity in exports and the results are shown in table 3.

It is clear from the table 3 that among the selected products, the exports were continuous both for cotton lint and cake of cotton seed for the past three decades period. Even though irregular exports were made for cotton seed before trade liberalization, the exports were continuous after participating in the international trade indicating the prevalence of comparative advantage for this commodity in the international market in the free trade regime (Gulati, 2001). Among the selected commodities/products, the exports' share in production was highest for cotton lint to a tune of 4% during the post-liberalization period and it was quite lower when compared to the pre-liberalization *period (4.88%). Similarly, the exports' share of cake of* cotton seed in its production had declined in the post-liberalization period (0.72%) when compared to pre-liberalization period (17.73%) This might be due to stiff competition in the international market, as other member nations are offering the same products at a competitive price (Varsha Varde, 2001). However, for cotton seed this share was slightly increased but non-significant. Regarding oil of cotton seed, no exports were made during the pre-liberalization period and irregular trend was exhibited during the post-liberalization period accounting for a meager share of only 0.01% in its production during 1999-2002. As a whole, the study revealed that, the share of the export of cotton seed and other products in their respective productions exhibited a gloomy picture, thereby indicating poor export orientation into the international market despite trade openness after 1991. The following might be the reasons which are cumulatively responsible for little export orientation of cotton seed and other products:

- High cost of production of these commodities adversely affected their export competitiveness in the international market.
- Restrictions from the importing countries regarding the *quality standards of the commodities/products.*
- Higher duties imposed by the importing countries.
- High unit export price of the commodities/products due to more internal storage, transportation and other related costs.

Table 3 Share of quantum of exports of cotton seed and other products in their respective productions before and after trade liberalisation

Commodity	Period	Average % share	Exports were nil during the period/year
Cotton seed	1978-81	0.004	1970 to 1977,1982,1983,
	1984-85	0.006	1986,1987, 1989 to 1991
	1992-02@	0.011	
Cotton lint	1970-90	4.880	-
	1991-02@	3. 989	
Oil of cotton seed	1999-02@	0.011	1970 to 1993, 1995, 1997, 1998
Cake of cotton seed	1970-90	17.727	-
	1991-02@	0.723	

@ = After trade liberalization; Raw data source: www.fao.org

The export scenario of cotton can be studied by analyzing the growth of exports both in terms of quantity and value and the analytical findings are presented in table 4.

The table 4 reveals that exports were regular for cotton lint and cake of cotton seed, when compared to cotton seed during past three decades period. However, the exports of cake of cotton seed showed disappointing picture, as indicated by the significant negative growth rates both in terms of quantity (16.24%) and value (15.75%) for the overall reference period, 1970-2002. Even during the selected sub-periods, the exports showed negative growth trends both for quantity and value of exports except during 1970-1980. For cotton lint, the decline in exports both in terms of quantity (23.23%) and value (23.43%) was accelerated during the post-liberalization period, thereby, leading to non-significant positive growth rates for the overall reference period. This clearly implies that, these products were less competitive in the international market. In case of cotton seed, the growth rates were worked only for the period, 1992-02 as the exports was regular during this period and the exports exhibited non-significant trend both in terms of quantity and value. Oil of cotton seed registered irregular exports during the selected reference period indicating its poor export orientation due to lack of competitiveness in the international market.

Table 4 Growth (%) of exports of cotton seed and other products from India

Commodity	Period	CGR		Exports were nil during the period/year
		Quantity	Value ($)	
Cotton seed	1992-02@	3.31NS	8.03NS	1970 to 1977,1982,1983, 1986,1987,1989 to 1991
Cotton lint	1970-80	-8.75NS	2.61NS	-
	1981-90	-4.63NS	-3.64NS	
	1991-02@	-23.23**	-23.43**	
	1970-02	0.64NS	1.72NS	
Oil of cotton seed	-	-	-	197010 1993,1995,1997, 1998
Cake of cotton seed	1970-80	6.31 **	15.14**	-
	1981-90	-27.71**	-28.93**	
	1991-02@	-30.62**	-29.66**	
	1970-02	-16.24**	-15.75**	

** = Significant at 1% level, NS = Non-significant
@ = After trade liberalization; Raw data source = www.fao.org

The import performance of the country with reference to cotton and its products was also studied, as India is the major importer of cotton from the international market. As the import data were available only for cotton and cotton lint for the past three decades period, the same were considered for the study and the growth analysis was done for the selected reference periods when the imports were regular and the analytical findings are presented in Table 5. The data reveals that imports were regular in case of cotton lint during the past three decades periods (except during 1984) when compared to cotton seed and oil of cotton seed, where imports were continuously made only for a shorter period 1977-84 and 1995-01 respectively. The analytical findings revealed that imports of cotton lint showed significant increasing trend both in terms of quantity (47.84%) and value (40.74%) during the post liberalization period, when compared to pre-liberalization periods, where imports showed continuous declining trend.

Table 5 Growth (%) of imports of cotton seed and other products both in terms of quality and value during the selected reference periods

Commodity	Period	CGR		Exports were nil during the period/year
		Quantity	Value ($)	
Cotton seed	1977-84	2.91NS	35.51*	1970 to 1976, 1985 to1993,1995 to 2002
Cotton lint	1970-83	-42.48**	-39.89**	1984
	1985-90	-31.41NS	-25.35NS	
	1991-02@	47.84**	40.74**	
Oil of cotton seed	1995-01@	0.04NS	-832NS	1970 to 1976,1979,1980, 1982 to 1994,2002
Cake of cotton seed	-	-	-	1970 to 1976,1978,1981 to 1983, 1985,1986, 1989 to 19%,1998,1999, 2002

** = Significant at 1% level, NS = Non-significant
@ = After trade liberalization; Raw data source = www.fao.org

This implies that after 1991 with the trade liberalization there was free flow of imports into the country without any restrictions so as to meet the domestic demand. Regarding cotton seed and oil of cotton seed, non-significant imports were made for the selected reference periods. For cake of cotton seed, the imports were irregular for most of the selected period and hence the computation of growth trends assumed no significance.

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Instructions for
Preparation of Manuscript for Journal of Oilseeds Research

Prospective author(s) are advised to consult the **Issue No. 27(1) June, 2010 of Journal of Oilseeds Research** and get them acquainted with the minor details of the format and style of the Journal. Meticulous compliance with the instructions given below will help quick handling of the manuscript by the reviewers, editor and printers. **Manuscripts are considered for publication in the Journal only from members of the ISOR**.

1. General

Full-length articles, short communications, book reviews and review articles are published in the Journal. Review articles and book reviews are published only by invitation. Full length articles and short communications should report results of original investigations in oilseeds, oil bearing plants and relevant fields of science. Choice of submitting the paper(s) either as full length paper or short communication rests with the authors. The Editor(s) or Reviewer(s) will examine *their suitability or otherwise only in that specific category. Each article should be written in English correctly, clearly,* objectively and concisely. All the statements made in the manuscript should be clear, unambiguous, and to the point. Telegraphic languages should be avoided. The data should be reported in a coherent sequence. Use active voice. Active voice is clear, unambiguous and takes less space. Use past tense while reporting results. Do not repeat ideas in different forms of sentences. Avoid superfluous sentences such as `it is interesting to note that', `it is evident from the table that' or `it may be concluded that' etc. Use % for percent, %age for percentage, / for per, @ for at the rate of hr for hours, sec for seconds. Indicate date as 21 January 2010 (no commas anywhere). Spell out the standard abbreviations when first mentioned eg. Net assimilation rate (NAR), general combining ability (gca), specific combining ability (sca), genetic advance (GA), total bright leaf equivalents (TBLE), mean sum of squares (MSS).

2. Manuscript

Language of the Journal is English. Generally, the length of an article should not exceed 3,000 words in the case of full-length article and 750 words in the case of short communication. However completeness of information is more important. Each half-page table or illustration should be taken as equivalent to 200 words. It is desirable to submit manuscript in the form of soft copy in a **compact disk (CD)** (in **MS Word document; double line space; Times New Roman; font size 12**) along with two hard copies of the manuscript in A4 size for faster handling and processing. Where facilities for computer typesetting are not available, two copies of the manuscript, typed on a good quality typing paper (foolscap or quarto size) or on bond paper and never on flimsily thin typing paper, should be submitted. To avoid hassles of the likely damage to the CD during the postal transit, the soft copy of the **revised and accepted article** should preferably submit through email to editorisor@gmail.com. In case of typed manuscripts, typing must be done only on one side of the paper, leaving sufficient margin, at least 4 cm on the left hand side and 3 cm on the other three sides. Faded typewriter ribbon should not be used. Double space typing is essential throughout the manuscript, right from the **Title** through **References** (except tables), foot note etc. Every page of the manuscript, including the title page, references, tables, etc. should be numbered. Punctuation marks help to show the meanings of words by grouping them into sentences, clauses, and phrases and in other ways. These marks should be used in proper manner if the reader of a paper is to understand exactly the intended meaning. Typeset (one soft copy + two hard copies) or typed manuscript (one original copy and a carbon copy), complete in all respects, are to be submitted to the Editor, Journal of Oilseeds Research, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030. This will be acknowledged by the office of the Society, giving a paper number which should be quoted in all subsequent correspondence regarding that particular manuscript.

3. Full-length Articles

Organization of the Manuscript

Before reading the instructions given below, the author(s) would better have a close look at the latest issue of the Journal.

Full-length article comprises the following sections.

(a) Short title
(b) Title
(c) Author/Authors
(d) Institution and Address with PIN (postal) code
(e) Abstract (along with key words)
(f) Introduction
(g) Materials and Methods
(h) Results and Discussion
(i) Acknowledgments (if any)
(j) References
(k) Tables and figures (if any)

Guidelines for each section are as follows:

All these headings or matter thereof should start from left hand side of the margin, without any indent.

Short Title

A shortened title (approximately of 30 characters) set in capital letters should convey the main theme of the paper.

Title

Except for prepositions, conjunctions, pronouns and articles, the first letter of each word should be in

capital letter. The title should be short and should contain key words and phrases to indicate the contents of the paper and be attractive. Jargons and telegraphic words should be avoided. In many cases, actual reading of the paper may depend on the attractiveness of the title.

Author/Authors

The name(s) of author(s) should be typed in capital letters a little below the title, starting from the left

margin. Put an asterisk on the name of the corresponding author. **Give the Email ID of the corresponding author as a footnote.**

Institution and Address

This matter will come below the name(s) of the author(s). Name of the Laboratory/Department, followed by the name of the Institution/Organization/University where the work reported in the paper was carried out shall come below the name(s) of author(s). Complete postal address, which should include city/town, district, and state, followed by PIN (postal) code is to be furnished. In case any author has left the above address, this should be indicated as a footnote.

Abstract

The paragraph should start with the word Abstract (in bold font). The abstract should comprise brief and factual summary or salient points of the contents and the conclusions of the investigation reported in the paper and should refer to any new information therein. As the abstract is an independent entity, it should be able to convey the gist of the paper in a concise manner. It will be seen by many more people than will read the paper. The abstract, as concise as possible, should not exceed 250 words in length. Everything that is important in the paper must be reflected in the abstract. It should provide to the reader very briefly the rationale, objectives or hypothesis, methods, results and conclusions of the study described in the paper. In the abstract, do not deflect the reader with promises such as 'will be discussed' or 'will be explained'. Also do not include reference, figure or table citation. At first mention in the abstract, give complete scientific name for plants and other organisms, the full names of chemicals and the description of soil order/series. Any such names or descriptions from the abstract need not be repeated in the text. It must be remembered that the abstracting journals place a great emphasis on the abstract in the selection of papers for abstracting. If properly prepared, they may reproduce it verbatim.

"Key words" should, follow separately after the last sentence of the abstract. "Key words" indicate the most important materials, operations, or ideas covered in the paper. Key words are used in indexing the articles.

Introduction

(To be typed as side-heading, starting from the left-hand margin, a few spaces below the key words)

This section is meant to introduce the subject of the paper. Introduction should be short, concise and indicate the objectives and scope of the investigation. To orient readers, give a brief reference to previous concepts and research. Limit literature references to essential information. When new references are available, do not use old references unless it is of historical importance or a landmark in that field. Emphasis should be given among other things on citing the literature on work done under Indian conditions. Introduction must include: (a) a brief statement of the problem, justifying the need for doing the work or the hypothesis on which the work is based, (b) the findings of others that will be further developed or challenged, and (c) an explanation of the approach to be followed and the objectives of the research described in the paper. If the methods employed in the paper are new, it must be indicated in the introduction section.

Materials and methods

(To be typed as side-heading, starting from the left-hand margin, a few spaces below the introduction)

This part of the text should comprise the materials used in the investigation, methods of experiment and analysis adopted. This portion should be self-explanatory and have the requisite information needed for understanding and assessing the results reported subsequently. Enough details should be provided in this section to allow a competent scientist to repeat the experiments, mentally or in fact. The geographical position of soil site or soils used in the experiment or site of field trial should be identified clearly with the help of coordinates (latitude & longitude) and invariably proper classification according to Soil Taxonomy (USDA), must be indicated to the level of Great-group, Suborder or Order as far as possible. Specify the period during which the experiment(s) was conducted. Send the article after completion of the experiment(s) not after a gap of 5 years. Instead of *kharif* and *rabi* use rainy and winter season respectively. Please give invariably the botanical names for local crop names like *raya, bajra moong, cholam* etc. Botanical and zoological names should confirm to the international rules. Give authorities. Go through some of our recent issues and find out the correct names. Give latest correct names from authentic source. For materials, give the appropriate technical specifications and quantities and source or method of preparation. Should a product be identified by trade name, add the name and location of the manufacturer or a major distributor in parenthesis after the first mention of the product. For the name of plant protection chemicals, give popular scientific names (first letter small), not trade names (When trade name is given in addition, capitalize the first letter of the name). Known methods of analysis should be indicated by referring to the original source, avoiding detailed description. Any new technique developed and followed should be described in fair detail. When some specially procured or proprietary materials are used, give their pertinent chemical and physical properties. References for the methods used in the study should be cited. If the techniques are widely familiar, use only their names in that case.

Results and Discussion

(To be typed as a side-heading, a few spaces below the matter on "Materials and Methods")

This section should discuss the salient points of observation and critical interpretation thereof in past tense. This should not be descriptive and mere recital of the data presented in the tables and diagrams. Unnecessary details must be avoided but at the same time significant findings and special features should be highlighted. For systematic discussion, this section may be divided into sub-sections under side-heading and/or paragraph side heading. Relate the results to your objectives. While discussing the results, give particular attention to the problem, question or hypothesis presented in the introduction. Explain the principles, relationships, and generalizations that can be supported by the results. Point out any exceptions. Explain how the results relate to previous findings, support, contradict or simply add as data. Use the Discussion section to focus on the meaning of your findings rather than recapitulating them. Scientific speculation is encouraged but it should be reasonable and firmly founded in observations. When results differ from previous results, possible explanations should be given. Controversial issues should be discussed clearly. References to published work should be cited in the text by the name(s) of author(s) as follows: Mukherjee and Mitra (1942) have shown or It has been shown (Mukherjee and Mitra, 1942)..... If there are more than two authors, this should be indicated by *et al.* after the surname of the first author, e.g., Mukherjee *et al.* (1938).

Always conclude the article by clearly crystallizing the summary of the results obtained along with their implications in solution of the practical problems or contribution to the advancement of the scientific knowledge.

Acknowledgments

(To be typed as given above, as a side-heading, well below the concluding portion of Conclusions)

The author(s) may place on record the help, and cooperation, or financial help received from any source, person or organization. This should be very brief, and omitted, if not necessary.

References

(To be typed as above, as side heading below Acknowledgement)

The list of references must include all published work referred to in the text. Type in double space. Do not cite anonymous as author; instead cite the name of the institute, publisher, or editor. References should be arranged alphabetically according to the surnames of the individual authors or first authors. Two or more references by the same author are to be cited chronologically; two or more in the same year by the letters a, b, c, etc. All individually authored articles precede those in which the individual is the first or joint author. Every reference cited in the article should be included in the list of References. This needs rigorous checking of each reference. Names of authors should not be capitalized.

The reference citation should follow the order: author(s), year of publication, title of the paper, periodical (title in full, no abbreviations, italics or underlined), volume (bold or double underlining), starting and ending pages of the paper. Reference to a book includes authors(s), year, title (first letter of each word except preposition, conjunction, and pronouns in capitals and underlined), the edition (if other than first), the publisher, city of publication. If necessary, particular page numbers should be mentioned in the last. Year of publication cited in the text should be checked with that given under References. Year, volume number and page number of each periodical cited under "References" must be checked with the original source. The list of references should be typed as follows:

Rao C R 1968. *Advances in Statistical Methods in Biometrical Research*, pp.40-45, John Wiley & Sons, New York.

Kanwar J S and Raychaudhuri S P 1971. *Review of Soil Research in India,* pp 30-36. Indian Society of Soil Science, New Delhi.

Mukherjee J N 1953. The need for delineating the basic soil and climatic regions of importance to the plant industry. *Journal of the Indian Society of Soil Science,* **1** : 1-6.

Khan S K, Mohanty S K and Chalam A B, 1986. Integrated management of organic manure and fertilizer nitrogen for rice. *Journal of the Indian Society of Soil Science,* **34** : 505-509.

Bijay-Singh and Yadvinder-Singh 1997. Green manuring and biological N fixation: North Indian perspective. *In:* Kanwar J S and Katyal J C (Ed.) *Plant Nutrient Needs, Supply, Efficiency and Policy Issues 2000-2025.* National Academy of Agricultural Sciences, New Delhi, India, pp.29-44.

Singh S, Pahuja S S and Malik R K 1992. Herbicidal control of water hyacinth and its effect on chemical composition of water *(in) Proceedings of Annual Weed Science Conference*, held during 3-4 March 1992 by the Indian Society of Weed Science, at Chaurdhary Charan Singh Haryana Agricultural University, Hisar, 127p.

AICRP on Soybean 1992. *Proceedings of 23rd Annual Workshop of All-India Co-ordinated Research Project on Soybean,* held during 7-9 May 1992 at University of Agricultural Sciences, Bangalore, Karnataka, National Research Centre for Soybean, Indore, pp.48.

Devakumar C. 1986. Identification of nitrification retarding principles in neem (*Azadirachta indica* A.Juss.) seeds. Ph D Thesis, Indian Agricultural Research Institute, New Delhi.

Reference to unpublished work should normally be avoided and if unavoidable it may be mentioned only in the text.

4. Short Communication

Conceptually short communication is a first report on new concept, ideas and methodology which the author(s) would wish to share with the scientific community and that the detailed paper would follow. Short Communication is akin to an advance booking for the report on the findings. Short communications may include short but trend-setting reports of field or laboratory observation(s), preliminary results of long-term projects, or new techniques or those matters on which enough information to warrant its publication as a full length article has still not been generated but the results need to be shared immediately with the scientific community. The style is less formal as compared with the "full-length" article. In the short communications, the sections on abstract, materials and methods, results and discussion, and conclusion are omitted; but the material is put concisely in the same sequence but without formal sections. The other instructions are the same as in the case of the full-length articles.

5. Tables

Tables should not form more than 20% of the text. Each table should be typed on separate sheet and should have on the top a table number (in Arabic numerals *viz.* 1, 2, 3 etc.) and a caption or title which should be short, but sufficiently explanatory of the data included in the table. Information in the table should never duplicate that in the text and vice versa. Symbols (asterisks, daggers, etc. or small letters, *viz.*, a, b, etc.) should be used to indicate footnotes to tables. Maximum size of table acceptable is what can be conveniently composed within one full printed page of the journal. Over-sized tables will be rejected out-right. Such tables may be suitably split into two or more small tables.

The data in tables should be corrected to minimum place of decimal so as to make it more meaningful. Do not use full stop with CD, SEm±, NS (not C.D., S.E.m±, N.S.). Do not put cross-rules inside the table. Tables should be numbered consecutively and their approximate positions indicated in the margin of the manuscript. Tables should not be inserted in the body of the text. Type each table on a separate sheet. Do not use capital letters for the tabular headings, do not underline the words and do not use a full-stop at the end of the heading. All the tables should be tagged with the main body of the text i.e. after references.

6. Figures

Figures include diagrams and photographs. Laser print outs of line diagrams are acceptable while dot-matrix print outs will be rejected. Alternatively, each illustration can be drawn on white art card or tracing cloth/ paper, using proper stencil. The lines should be bold and of uniform thickness. The numbers and letterings must be stenciled; free-hand drawing will not be accepted. Size of the illustrations as well as numbers, and letterings should be sufficiently large to stand suitable reduction in size. Overall size of the illustrations should be such that on reduction, the size will be the width of single or double column of the printed page of the Journal. Legends, if any, should be included within the illustration. Each illustration should have a number followed by a caption typed/ typeset well below the illustration.

Title of the article and name(s) of the author(s) should be written sufficiently below the caption. The photographs (black and white) should have a glossy finish with sharp contrast between the light and the dark areas. Colour photographs/ figures are not normally accepted. One set of the original figures must be submitted along with the manuscript, while the second set can be photocopy. The illustrations should be numbered consecutively in the order in which they are mentioned in the text. The position of each figure should be indicated in the margin of the text. The photographs should be securely enclosed with the manuscript after placing them in hard board pouches so that there may not be any crack or fold. Photographs should preferably be 8.5 cm or 17 cm wide or double the size. The captions for all the illustrations (including photographs) should be typed on a separate sheet of paper and placed after the tables.

7. Expression of Plant Nutrients on Elemental Basis

The amounts and proportions of nutrient elements must be expressed in elemental forms e.g. for ion uptake or in other ways as needed for theoretical purposes. In expressing doses of nitrogen, phosphatic, and potassic fertilizers also these should be in the form of N, P and K, respectively. While these should be expressed in terms of kg/ha for field experiments, for pot culture studies the unit should be in mg/kg soil.

8. SI Units and Symbols

SI Units (System International d 'Unities or International System of Units) should be used. The SI contains three classes of units: (i) base units, (ii) derived units, and (iii) supplementary units. To denote multiples and sub-multiples of units, standard abbreviations are to be used. Clark's Tables: Science Data Book by Orient Longman, New Delhi (1982) may be consulted.

Some of these units along with the corresponding symbols are reproduced for the sake of convenience.

Names and Symbols of SI Units

Physical Symbol for SI Unit Symbol Remarks quantity physical quantity for SI Unit

Primary Units

Length	l	Time	t
metre	m	second	s
Mass	m	Electric current	I
kilogram	kg	ampere	A

Secondary Units

Plane angle	radian	rad
Solid angle	steradian	sr

Unit Symbol

centimetre	cm	microgram	μg
cubic centimetre	cm^3	micron	μm
cubic metre	m^3	micronmol	μmol
day	d	milligram	mg
decisiemens	dS	millilitre	mL
degree-Celsius	^0C [= (F - 32) × 0.556]	minute	min
gram	g	nanometre	nm
hectare	ha	newton	N
hour	h	pascal	Pa
joule J	(= 10^7 erg or 4.19 cal.)	second	s
kelvin	K (= ^0C + 273)	square centimetre	cm^2
kilogram	kg	square kilometre	km^2
kilometre	km	tonne	t
litre	L	watt	W
megagram	Mg		

Some applications along with symbols

adsorption energy:	J/mol (= cal/mol × 4.19)	leaf area	m^2/kg
cation exchange capacity:	cmol (p+)/kg (= m.e. /100 g)	nutrient content in plants (dry matter basis)	μg/ g, mg/g or g/kg
electrolytic conductivity:	dS/ m (= mmhos /cm)		
evapotranspiration rate:	$m^3/m^2/s$ or m/s	root density or root length density	m/m^3
heat flux	W/m^2	soil bulk density	Mg/m^3 (= g/cm^3)
gas diffusion:	$g/m^2/s$ or $m^3/m^2/s$ or m/s	specific heat	J /kg/K
water flow	$kg/m^2/s$ (or) $m^3 m^2$ s (or) m /s	specific surface area of soil	m^2/kg
gas diffusivity	m^2/s	thermal conductivity	W/m/K
hydraulic conductivity	m/s	transpiration rate	mg/ m^2/ s
ion uptake (per kg of dry plant material):	mol/kg	water content of soil	kg/kg or m^3/m^3
		water tension	kPa (or) MPa

While giving the SI units the first letter should not be in capital i.e cm, not Cm; kg not Kg. There should not be a full stop at the end of the abbreviation: cm, not cm. kg, not kg.; ha, not ha.

In reporting the data, dimensional units, viz., M (mass), L (length), and T (time) should be used as

shown under some applications above. Some examples are: 120 kg N/ha; 5 t/ha; 4 dS/m etc.

9. Special Instructions

i. In a series or range of measurements, mention the unit only at the end, e.g. 2 to 6 cm^2, 3, 6, and 9 cm, etc. Similarly use cm^2, cm^3 instead of sq cm and cu m.

ii. Any unfamiliar abbreviation must be identified fully (in parenthesis).

iii. A sentence should not begin with an abbreviation.

iv. Numeral should be used whenever it is followed by a unit measure or its abbreviations, e.g., 1 g, 3 m, 5 h, 6 months, etc. Otherwise, words should be used for numbers one to nine and numerals for larger ones except in a series of numbers when numerals should be used for all in the series.

v. Do not abbreviate litre to` l' or tonne to `t' spell out.

vi. Before the paper is sent, check carefully all data and text for factual, grammatical and typographical errors.

vii. Do not forget to attach the original signed copy of `Article Certificate' (without any alteration, overwriting or pasting) signed by all authors.

viii. On revision, please answer all the referees' comments point-wise, indicating the modifications made by you *on a separate sheet* in duplicate.

ix. If you do not agree with some comments of the referee, modify the article to the extent possible. Give reasons (2 copies on a separate sheet) for your disagreement, with full justification (the article would be examined again).

x. Rupees should be given as per the new symbol ₹ approved by Govt. of India.

Important Instructions

i. Data on field experiments have to be at least for a period of 2-3 years

ii. Papers on pot experiments will be considered for publication only as short communications

iii. Giving coefficient of variation in the case of field experiments Standard error in the case of laboratory determination is mandatory. For rigorous statistical treatment, journals like Journal of Agricultural Science Cambridge, Experimental Agriculture and Soil Use and Management should serve as eye openers.

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ANNOUNCEMENT

The Indian Society of Oilseeds Research introduces two awards *viz*., **ISOR Best Research Paper Award and ISOR Best Ph.D. Thesis Award.**

ISOR best research paper award will be given from year 2009 annually. Award carries a certificate and cash prize of **₹ 5,000/-**. All the full research papers published in a year are eligible for the award. The award shall be given for notable and original research work and not for routine investigations.

ISOR best thesis award will be given from the year 2010 annually. Award carries a citation and cash prize of **₹10,000/-**. The award is open to all Indian students in the field of oilseeds research. Only those theses are considered for the award for which final *viva-voce* is completed by 31st December of that particular year.

The awards are presented during National/International Symposiums organised by the ISOR. For further details please contact **General Secretary, Indian Society of Oilseeds Research, Directorate of Oilseeds Research, Rajendranagar, Hyderabad – 500 030 or mail to: oilseedsociety@gmail.com**

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