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Seed dormancy in oilseeds with special reference to sunflower - A Review

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Abstract

Seed dormancy is the inability of viable seeds to germinate in the presence of otherwise favourable conditions of temperature, moisture and oxygen supply due to block in sequence of metabolic processes. Hence, it is a complex representative of the control mechanisms that regulates the resumption of the embryo growth through interactions between seed and environment. Various parameters *viz.*, causes of seed dormancy, biochemical changes, hormonal regulation of dormancy, environmental control of seed dormancy and methods to overcome seed dormancy were reviewed.

Key words : Seed dormancy, sunflower

The nature of dormancy is usually associated with the tissues enclosing embryo or embryo itself. In both the cases the embryo is unable to overcome the constraints. Therefore, seeds, usually fail to germinate due to (1) immature embryos, (2) impermeability of seed coats, to water and or gases, (3) presence of inhibitors, (4) physiological immaturity, (5) light sensitivity and (6) mechanical resistance of seed coats (Maguire, 1984). Based on the manner of origin, seed dormancy can be classified into two main groups *viz.*, (a) primitive or innate dormancy where the dormancy is inherent in the seed by the end of seed development, irrespective of ambient environmental conditions (b) secondary or induced dormancy where, mature imbibed seeds remain dormant due to unsuitable temperatures, anoxia, very low soil water potentials or illumination etc., (Maguire, 1984).

Genetic control of seed dormancy

In many cases, dormancy is reported to be innate, a heritable character. It has been observed that the interaction between maternal and embryonic genotypes regulated seed dormancy in sunflower (Zimmerman and Zimmer, 1978)

Inheritance of dormancy

It was also opined that dormancy was partially dominant in dormant seeds over non dormant ones (Ramachandran *et al.*, 1967). Further, it is controlled by the interactions of genes in either heterozygous or homozygous condition.

Seed structure in relation to dormancy

Dormancy in seeds is imposed through several of their structures surrounding the embryo , such as endosperm, cotyledons, nucellus, testa etc., or by certain chemical inhibitors (ABA) in these seed structures (Degivry *et al.*, 1990). More often, it is the maternal tissue in the seed such as pericarp and / or seed coat that induce dormancy. Some reports also indicated the role of embryo in induction of dormancy (Cseresnyes *et al.*, 1987).

Among the various seed structures pericarp, seed coat , embryo and cotyledons play a predominant role in induction of dormancy. The involvement of pericarp and embryo is more in crops like sunflower (Udayakumar and Krishnasastry, 1974).

Dormancy in sunflower is due to both endogenous and exogenous factors. Endogenous factors are associated with that of seed coat. The duration of influence of these factors follow that of the duration of seed developmental stages (Sudhakar Babu personal communication).

In a typical developing sunflower seed, the dormancy inducing factors appear first in the pericarp, get translocated to the seed coat, and then to the cotyledon, and finally, to the embryo from 20th day after anthesis (DAA) (Krishnamurthy, 1990). In the absence of embryo, such as an unfertilized achene, much of the dormancy inducing factors remain in the pericarp. Induction of seed dormancy by these factors begins at about 10th DAA . By 20th DAA , the accumulated factors in the maternal structure begin to mobilise to the cotyledons and embryo. At maturity or harvest i.e., 30th DAA the dormancy inducing factors begin to degrade. This degradation of dormancy inducing factors is rapid in the embryonic tissues than in the pericarp (Krishnamurthy, 1990). The transport of dormancy inducing factors into the embryos at early stages may interfere with the normal development and maturational process, thus making the seed dormant.

The dormancy inducing capability of a structure can be monitored by treating the seeds with the aqueous extracts

Short communications

Role of inhibitors (ABA) in seed dormancy

Earlier, it was thought that the dormancy is mainly due to the presence of inhibitors in the seed coat, but later it was reported that dormancy was also due to inadequacies of the embryo either it may be a immature or rudimentary embryo (Bewley and Black, 1994). But, the intensity of the dormancy depends on the ratio of germination promoters to inhibitors in the embryo. Sunflower seeds with deepest dormancy were reported to contain ABA about 1.5 mg/g dryweight of seeds and in less dormant embryos it would be 0.2 mg/g dryweight. Hence, *in situ* ABA synthesis was necessary to impose and retain the embryo dormancy in sunflower (Lepage and Garello, 1992). In sunflower, *in vitro* culture of immature embryos isolated at different times after anthesis showed that the youngest embryos were able to germinate, but within the 3rd week after pollination, dormancy progressively affected most of the embryos (Degivry *et al.*, 1990). Certain endogenously extracted substances were reported to be inhibitory and were closely related to the inhibitor *viz.*, abscisic acid. Germination of nondormant seeds was inhibited by the exogenous application of ABA.

The regulation of seed dormancy by ABA may be direct or indirect in many plant species. It may suppress the action of germination specific proteins *viz.*, those that are expressed in the presence of gibberellic acid or may raise the levels of ABA specific proteins. Further, embryos have limited access to water uptake in the presence of ABA (Maguire, 1984).

Role of ethylene in seed dormancy

The endogenous stimulator of germination i.e., ethylene reverses the effect of abscisic acid in oilseeds when it is coupled with kinetin. It is a powerful initiator of precocious germination at a concentration of 0.5 - 1000 ppm (David and Heather, 1990).

Environmental control of seed dormancy

The expression of seed dormancy in seeds is influenced by particular environmental conditions such as temperature and light. The specific triggering actions of temperature and light are important in breaking seed dormancy. For germination to occur, seed necessarily undergo a period of "After-ripening". The duration of it varies among the genotypes and within the genotypes. Adverse environmental conditions may induce secondary dormancy as reported in sunflower (Corbineau *et al.*, 1987).

Phytochrome mediated control of seed dormancy

Phytochrome controlled seeds specifically require red (R) irradiance to germinate. The pigment (Phytochrome) is believed to be present in the dormant seeds as Pr (i.e., Phytochrome red absorbing form) and it gets converted into Pfr by R-irradiance. The Pfr is biologically active and it absorbs far red light. Pfr is reported to be synthesized in the embryo and cytoledons. Phytochrome acts by activating hormonal systems and release gibberellic acid and cytokinin, or by altering the membrane behaviour along with gibberellic acid (Agarwal, 1981).

Effect of temperature and seed dormancy

Induction of secondary dormancy due to suboptimal temperatures usually referred to thermodormancy and it was observed in seeds of different species (Corbineau *et al.*, 1987). In sunflower high temperature at 45°C for 48 hours inhibited germination. Even at optimum temperature of 25°C, seeds exposed to high temperature resulted in more abnormal seedling growth. Ethylene @ 55 ml per litre improved germination of thermodormant seeds at 25°C (Corbineau *et al.*, 1987). They also reported that CO_2 enriched atmosphere and dry storage conditions improved germination in sunflower. Thus, the induction of thermodormancy in sunflower seems to be associated with loss of their ability to convert alpha - amino cyclo prophyl carboxylic acid (ACC) to ethylene (Corbineau *et al.*, 1987).

Seasonal effects and duration of seed dormancy

From the earlier literature, it is evident that the period of dormancy duration varied widely among the species and within the species. Dormancy period also varies within the species. Dormancy period also varies with the season. The mean duration of dormancy in few cultivars of sunflower was about 33 days during summer as against 48 days in winter (Srivastava and Dey, 1982). However, sunflower seeds harvested in *kharif* remained dormant for a longer period of 55 days after harvest (Singh *et al.*, 1990). The degree of dormancy among sunflower genotypes varied from 12-55 days (Cseresnyes, 1979, Cseresnyes *et al.*, 1987).

Effect of seed position

The position of the seed in relation to dormancy was, studied in sunflower. Germination was maximum in the seed harvested from outer florets of the capitulum and it increased with the delay in testing period from 15-55 days after harvest in male sterile and maintainer lines, indicating the existence of dormancy of 55 days (Singh and Shete, 1992).

The occurrence and release of dormancy with reference to the development is a stepwise phenomena in which the embryos of sunflower are capable of germination at first stage of 12-16 days after fertilization followed by deep dormancy in the second stage of 20-30 days after fertilization due to the physiological properties of the seed coats and embryos. Embryos at this stage do not germinate but they gain germination capacity gradually during the 3rd stage i.e., 40 days after fertilization (Ramazunova, 1994).

of the concerned structures from dormant seeds. This helps in the easy detection of soluble chemical inhibitors of germination. Hence, dormancy may be due to the presence of inhibitors rather than the hard seed coat (Dighe and Patil, 1980). This is further confirmed from the fact that seed coat in sunflower is not that much hard to prevent the entry of water and oxygen causing dormancy (Singh *et al.*, 1990).

Biochemical changes in seed dormancy

Based on biochemical aspects, varieties can be grouped into dormant and nondormant types.

Changes in phenolic contents

Generally, it is understood that phenolic compounds play an important role for occurrence of dormancy in seeds. In case of sunflower, it was reported to be of phenolic type(Lane, 1965). Some of the phenolic acids responsible for inhibition of germination and growth were identified as phenolic (Hydro benzoic acid), cinnamic acid (Cinnamic and ferulic) and unsaturated lactones *viz.*, coumaric and paraascorbic acid (Ketring, 1973). It is obvious from the literature that the higher amounts of the above phenolic compounds have an additive inhibitory effect on germination in dormant sunflower types compared to nondormant ones.

Changes in enzymatic levels

During germination, soluble amino acids accumulate in the reserve tissue and to a greater extent in the embryos. The two key enzymes of amino acid metabolism viz., Glutamate dehydrogenase (GDH) and Glutamate oxaloacetate transaminase (GOT) show lower activity in dormant seeds. In the initial phase of germination these enzymes are activated and help in earlier sustained increase in embryo growth . In the 2nd exponential phase of embryo growth higher enzymatic activity as well as their synthesis is desirable to meet the greater amino acid requirement. Dormancy in seeds is thus due to block in the synthesis of GOT (Sengupta and Mangalik, 1987).

The dormant sunflower seeds contained low polyphenol oxidase activity in the cotyledons compared to its higher activity during germination. However, no significant change in chlorogenic acid was observed during germination.

Changes in fatty acid and protein composition

In nondormant seeds of groundnut (cv. J-11), the total fat content decreased with time during imbibition compared to little change in the fresh dormant seeds of (cv.M-13). Depletion of lipids during the after- ripening period release the seeds from dormancy. This is apparent from unaltered depletion of storage lipids in seeds treated with ABA, which inhibited the protein hydrolysis to a greater extent rather then the lipid hydrolysis in germinating seeds. Similar effects were observed in nondormant seeds when treated with ABA (Arunasharma and sengupta.1987).

Respiratory pathways in relation to dormancy

Pentose phosphate pathway (PPP) , an oxygen requiring process is essential for breaking dormancy in seeds. Roberts and Smith (1977) proposed that PPP is not operative in dormant seeds because of limitation in the rates of reaction of reoxidation of NADPH. The initiation of germination in dormant seeds in presence of hydrogen acceptors, such as nitrate, nitre, methylene blue, terminal oxidase inhibitors *viz.*, cyanide, azide is assumed to be mediated through reoxidation of NADPH and stimulation of PPP. These proposals were based on the research reports of Agarwal and Canvin (1971) wherein the ratio of C6/C1 less than unity is an indication of PPP.

Hormonal regulation of seed dormancy

Dormancy may block a number of sequential developmental processes. It is a complex representative of the control mechanisms that regulate the embryo growth through the interactions between seed and environment. The response of seeds to environment may be translated into cellular control systems involving certain hormones, which influence the metabolic activities within the seed. The hormones that promote germination are gibberellic acid, ethylene and that inhibits germination is abscisic acid. Hence, a balance between inhibitors and promoters in embryo and other parts of the seed regulate dormancy and germination (Bewley and Black, 1994)

Role of gibberellins and cytokinins in seed dormancy

Gibberellic acid level in seed correlates with increase in ribonucleic acid where as cytokinins neutralize abscisic acid inhibition. The role of inhibitors and cytokinins in dormancy release are secondary (Agarwal, 1981).

Site of perception of growth hormones in dormant seeds

The process of after-ripening alters the levels of these inhibitors and promoters. Leaching, temperature treatment, addition of effective chemicals such as coumarin, thiourea, potassium nitrate also alter the levels of these inhibitors and promoters. Dormancy regulation in seeds is a complicated process governed not only by an appropriate hormonal balance, but also by certain other compounds like phenolics which seem to have a regulatory role either directly or indirectly. A radioimmuno-assay of sunflower embryo showed that the endogenous ABA level, which increased sharply in the first half of the developmental period fell precisely the moment when embryo dormancy became established. Application of fluoridone before the increase of ABA level prevented both ABA synthesis and the onset of embryo dormancy. But, in situations where ABA level is more, application of fluoridone can not prevent the occurrence of dormancy in embryo. Thus, dormancy appears to be ABA dependent (Degivry *et al.*, 1990).

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After-ripening and seed dormancy

During maturation, the embryo approaches developmental arrest, wherein the growth is primarily by the accumulation of dryweight, with only a low frequency of cell division and expansion (David and Heather, 1990). At the time of seed maturity, the balance in promoter - inhibitor is more towards inhibitors component, imposing dormancy (Wareing and Saunders, 1971).

The physiological age of the seeds markedly influence their germination response as seeds usually become less dormant with time. Mature seeds of sunflower exhibiting dormancy will be eliminated during storage in dry conditions (Corbineau and Come, 1987). *In vitro* culture of immature embryos isolated at different times after anthesis showed that the youngest embryos were able to germinate, but within the 3rd week after pollination dormancy progressively affected most of the embryos. During after-ripening, the inhibitor is possibly converted through the metabolism to the formation of other substances which release seeds of imposed chemical dormancy (Krishnamurthy, 1990).

Methods to overcome seed dormancy

Various empirical methods that overcome dormancy and induce germination are as follows:

1. **After-ripening**: It is a physiological process that alters the composition of substances, maintains the balance in the levels of inhibitors and stimulators and enhances the respiratory rate or increase stimulator level. During chilling, the water soluble inhibitors leach out and growth promoters increase in quantity (Maguire, 1984).

2. **Suitable temperature regime**: It is established that by stratification or by exogenous application of growth promoters germination could be induced in dormant seeds (Wareing and Saunders, 1971). Prechilling hastens the post-harvest maturation, reduction in ABA and increase in GA content (Diaz and Martin, 1972).

3. **Hot water treatment**: It is an effective method of breaking hardness in legumes. Seeds are soaked in water at 80 °C for 1-5 min before testing for germination (Anonymous, 1984).

4. **A simple cut or injury**: It facilitates leaching of inhibitors from various components of seed and release the seed from dormancy (Maguire, 1984).

5. **Exit of inhibitors or neutralization**: By leaching seeds in water solutions of promoter or by placing them in activated carbon (Maguire, 1984).

6. **Chemical treatment**: Chemical treatment with certain compounds such as potassium nitrate, thiourea, gibberellins, ethrel, kinetin and indole acetic acid effectively promote germination of dormant seeds. The effectiveness of these vary with the species. The combination of promoters is more effective (Hendricks and Taylorson, 1972). These chemicals stimulate germination, by influencing the enzyme systems involved in the various metabolic phases of germination process. The effects of few of these chemicals are listed below:

   a. **Ethrel**: Ethrel at different concentrations break seed dormancy in a variety of crops. It increases the activity of peroxidase and protein synthesis (Srivastava and Dey, 1982). In sunflower, its effects were apparent at 25 ppm (Udayakumar and Krishnasastry, 1975); 50 ppm and 60 ppm (Cseresnyes *et al.*, 1987) and 250 ppm (Srivastava and Dey, 1982). The per cent germination was higher, when sunflower seeds were soaked in the ethrel solution for 6 - 12 hrs (Patil *et al.*, 1992).

   b. ***Gibberellic acid***: Its release of seed dormancy is related to the production of α-amylase in the aleurone layers of seed (Maguire, 1984). In sunflower, gibberellic acid effects were clearly evident when it was applied at a concentration of 3 ppm (Udayakumar and Krishnasastry, 1975); 100 ppm (Srivastava and Dey, 1982); 60 ppm (Cseresnyes *et al.*, 1987).

   c. **Cytokinin**: Its treatment is also effective in releasing dormancy of seeds in sunflower (Srivastava and Dey, 1982). They increase the endogenous IAA levels and thereby release the ethylene and relieve the seeds from dormant phase.

   d. ***Benzyl adenine***: In sunflower, benzyl adenine at a concentration of 2 ppm as effective in breaking seeds dormancy (Udayakumar and Krishnasastry, 1975).

   e. **Potassium nitrate**: It is effective at a concentration of 0.2% (Deshpande *et al.*, 1992) and 1-2% (Ankaiah *et al.*, 1993) in breaking dormancy of seeds in sunflower.

   f. **Boric acid**: At a concentration of 1.5 mg/litre boric acid was also effective in overcoming seed dormancy in sunflower (Zouzou and Oubouchat, 1988).

From the foregoing it is evident that growth regulators as well as certain agricultural compounds can effectively aid in overcoming seed dormancy in sunflower.

Table 1 Pooled analysis of variance for seed yield per plant and related traits of sixteen *toria* genotypes

Source	df	Mean squares								
		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Siliquae/ plant	Seeds/ siliqua	Siliqua length (cm)	1000 seed weight (g)	Seed yield/ plant (g)
Environment (E)	1	2.04**	2.67**	109.87**	2.02**	1102.97**	27.74**	0.91**	0.43**	21.57**
Replication (n/E)	4	0.65	3.12**	1.03	0.31	83.72	0.03	0.04	0.01	0.13
Genotype (G)	15	12.66**	69.33**	439.72**	2.31**	7194.68**	19.19**	0.69**	0.61**	5.51**
G x E	15	0.66	1.60**	1.04	0.15	66.66	0.91	0.01	0.02	0.07
Pooled error	60	0.24	0.38	1.94	0.09	71.39	0.23	0.01	0.01	0.66

** Significant at 1% level

Table 2 Estimates of genetic parameters for different characters of 16 *toria* genotypes obtained from pooled analysis

Components	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Siliquae/ plant	Seeds/ siliqua	Siliqua length (cm)	1000 seed weight (g)	Seed yield/ plant (g)
Mean	29	105	73.5	4.3	157.7	18.6	5.7	3.0	9.6
Range	26-32	97-109	59.8-86.9	3.5-6.4	100.3-234.9	16.9-25.7	5.3-3.8	2.6-3.8	7.7-11.8
GCV (%)	4.8	3.2	14.5	12.1	21.1	8.6	5.6	9.8	9.2
Heritability (%)	94.7	97.7	99.7	93.7	98.9	95.2	98.3	97.2	82.5
GA as % of mean	9.6	6.5	29.7	24.1	43.2	17.3	11.5	20.9	17.1

** *Significant at 1% level*

High heritability in broad sense was recorded for all the characters. It ranged from 82.5% in seed yield per plant to 99.7% in plant height. High estimates of heritability observed for all the traits indicated lower environmental effects and revealed reliability in phenotypic selection. High heritability for yield and different yield attributes was also observed by Chowdhury and Chaudhury (1970) in brown *sarson*, Chowdhury *et al.* (1981) in *toria* Barman (1994) in rapeseed. Genetic advance as percentage of mean was high in siliquae per plant (43.2%), plant height (29.7%) and primary branches per plant (24.1%) and moderate in 1000 seed weight (20.9%), seeds per siliqua (17.3%) and seed yield per plant (17.1%). The other characters showed relatively low estimate of genetic advance. Similar results were also reported by Chowdhury and Chaudhury (1970) in brown *sarson*.

High heritability associated with high genetic advance as observed in siliquae plant^{-1}, primary branches plant^{-1} and plant height revealed predominance of additive gene action for these characters and thus ensured reliability for direct selection.

A positive response to mass selection was observed in all the 16 *toria* genotypes for all the four characters studied *viz.*, primary branches per plant, siliquae per plant, seeds per siliqua and seed yield per plant (Table 3). However, the percentage of improvement was relatively higher for primary branches per plant (up to 30.2%) followed by seed yield per plant (up to 12.7%). In case of primary branches per plant, the genotypes showing greater improvement (>20%) were JT-4, JT-3, JT-12, JT-9, JT-10 and JT-22. Three genotypes *viz.*, M-27, JT-6 and JT-7 showed relatively better improvement (>5%) for siliquae per plant while, five genotypes, *viz.*, JT-11, JT-8, TS-38, M-27 and JT-6 showed better improvement (>5%) for seeds per siliqua. The genotypes showing relatively greater improvement (>10%) for seed yield per plant were JT-3, JT-6, JT-12, JT-4, JT-11 and TS-38. After one cycle of mass selection, Chaubey (1979) also observed an yield improvement of 8.2% and 15.4% in two populations of *toria*, respectively.

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Genetic variability and effect of mass selection in *toria* (*Brassica campestris* var. *toria*)

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Abstract

In an experiment conducted on 16 *B. campestris* Var. *toria* lines, under two sowing dates, high genotypic coefficient of variation was recorded for siliquae per plant and moderate for plant height and primary branches per plant. Estimates of heritability in broad sense were high for all the characters ranging from 82.5 to 99.7%. Genetic advance as percentage of mean was high for siliquae per plant and moderate for plant height, primary branches per plant and 1000 seed weight. Response to mass selection was positive in all the four characters studied *viz.*, primary branches per plant, siliquae and seed yield per plant. However, realized genetic gains as percentage of mean were relatively higher for primary branches per plant (upto 30.2 %) and seed yield per plant (upto 12.3 %).

Key words : *Toria*, genetic variability, heritability, mass selection, selection response

Introduction

Presence of genetic variability is one of the pre-requisites to perform selection in any breeding material. Response to phenotypic selection for a character depends mainly on variability, heritability and selection intensity. Therefore, genetic analysis is very important for an efficient mass selection programme. The potency of a character for effective selection can be judged rationally through combined assessment of heritability and genetic advance. In *Brassica* crops, yield and different yield attributes with high heritability and genetic advance were reported to be selected successfully (Chowdhury and Chaudhury, 1970; Gupta, 1972; Chowdhury *et al.*, 1981). The present experiment was planned to study genetic variability and effect of mass selection in *toria* (*Brassica campestris* var. *toria*).

Materials and methods

The present study was conducted in the experimental field of the Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat during *rabi*, 1994-95. The experimental material consisted of 13 Jorhat *toria* (JT) lines developed through intervarietal crosses which had been advanced to attain the population equilibrium level and three other *toria* lines. All these 16 lines were grown under normal (sown on 10th November, 1994) and late sowings (sown on 10th December, 1994) in a randomized block design with three replications. Recommended package of practices was followed to raise the crop. Observations were recorded for nine yield and yield attributing characters to analyze genetic variability and its related parameters. Response to mass selection was studied on normal sown *toria* lines with four characters *viz.*, number of primary branches per plant, siliquae per plant, seeds per siliqua and seed yield per plant.

Pooled analysis of variance was made with appropriate statistical procedure (Gomez and Gomez, 1984). Genotypic and phenotypic variances were obtained from the pooled analysis of variances and were used to estimate genotypic coefficient of variation (GCV) and heritability in broad sense (h^2 b s) according to Allard (1960). Realized genetic gain or response to selection was estimated according to Simmonds (1981).

Results and discussion

On pooled analysis of variances, significant differences were observed both for genotypes and environments in all the nine characters studied (Table 1). The significant effect of environment indicates that sowing time had a great influence on all the characters. Saini *et al.* (1985) also reported significant influence of sowing dates on growth and yield of rapeseed and mustard. Genotype x environment interaction was significant only for days to maturity.

Genetic parameters obtained from pooled analysis of variances (Table 2) revealed high estimate of genotypic coefficient of variation for siliquae per plant (21.1%), while it was moderate for plant height (14.5%) and primary branches per plant (12.1%). The remaining characters showed relatively lower genetic variation. Similar observations were reported by Chowdhury *et al.* (1981) and Singh (1986) in *toria*.

Mass selection becomes effective for the characters with high heritability and genetic variability. In the present study, all the four characters used for mass selection exhibited high heritability and moderate to high genetic variability and thus resulted in positive response to selection.

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Table 3 Progeny means of selected (X_s) and unselected population (X_0) and their genetic gain (X_s-X_0) in 16 *toria* lines

Genotype	Primary branches/plant			Siliquae/plant			Seeds/siliquae			Seed yield/plant		
	X_s	X_0	X_s-X_0	X_s	X_0	X_s-X_0	X_s	X_0	X_s-X_0	X_s	X_0	X_s-X_0
JT-1	5.40	4.90	0.50 (10.2)	169.86	169.30	0.56 (0.3)	19.33	19.00	0.33 (1.7)	10.00	9.26	0.74 (7.9)
JT-2	4.80	3.90	0.90 (23.1)	120.13	116.83	3.30 (2.8)	19.83	19.13	0.70 (3.7)	11.50	11.00	0.50 (4.5)
JT-3	3.00	3.90	1.10 (28.2)	191.03	182.30	8.73 (4.7)	19.66	19.10	0.56 (2.9)	11.00	9.76	1.24 (12.7)
JT-4	5.60	4.30	1.30 (30.2)	152.50	148.10	4.40 (2.9)	20.83	20.20	0.63 (3.1)	11.00	9.90	1.10 (11.1)
JT-5	4.86	4.10	0.76 (18.5)	154.43	147.63	6.60 (4.50)	19.83	19.60	0.23 (0.6)	10.17	9.70	0.47 (4.8)
JT-6	4.90	4.20	0.70 (16.7)	183.80	173.80	10.00 (5.8)	20.66	19.66	1.00 (5.1)	10.67	9.50	1.17 (12.3)
JT-7	4.20	4.10	0.10 (2.4)	180.16	171.30	8.86 (5.2)	20.83	19.83	1.00 (5.0)	11.33	10.33	1.00 (9.6)
JT-8	4.76	3.90	0.86 (22,1)	129.06	123.00	6.06 (4.9)	21.00	19.80	1.20 (6.0)	10.33	9.66	0.67 (6.9)
JT-9	5.16	4.10	1.06 (25.9)	158.06	153.43	4.63 (3.0)	19.50	18.76	0.74 (3.9)	12.17	11.16	1.01 (9.1)
JT-10	5.13	4.10	1.03 (25.1)	165.03	159.36	5.67 (3.6)	10.66	19.73	0.93 (4.7)	10.67	10.33	0.34 (3.1)
JT-11	4.86	4.30	0.56 (13.0)	130.23	124.23	6.00 (4.8)	21.66	19.50	1.66 (8.5)	11.00	10.00	1.00 (10.0)
JT-12	4.83	3.80	1.03 (27.1)	107.26	103.23	4.03 (3.9)	19.33	19.03	0.30 (1.6)	10.83	9.66	1.17 (12.1)
JT-13	4.20	4.10	0.10 (2.4)	178.60	173.83	4.77 (2.7)	19.16	19.00	0.16 (0.8)	11.50	11.00	0.50 (4.5)
TS-3	6.14	5.40	0.74 (13.7)	208.86	200.16	8.70 (4.3)	21.33	20.16	1.17 (5.8)	11.00	10.00	1.00 (10.0)
BT-2	5.56	4.60	0.96 (20.9)	200.16	195.43	4.73 (2.4)	21.66	20.03	1.63 (3.1)	11.67	11.16	0.51 (4.6)
M-27	6.43	5.90	0.53 (8.9)	238.73	221.70	16.83 (7.5)	26.33	25.00	1.33 (5.3)	12.67	11.16	1.01 (9.1)
CD (0.05)	0.40	0.60	-	8.25	10.08	-	1.54	0.71	-	0.82	0.87	-

* Figures in parenthesis indicate percentage of improvement

Results and discussion

The conventional multilocation analysis of variance did not give any information about the response of individual varieties to different environments (Comstock and Moll, 1963). Several authors have suggested different types of analysis to identify stable genotype as indicated above.

Significant differences among the genotypes in individual as well as pooled environments indicated that they differed in the five characters namely plant height, number of branches per plant, number of capsules per plant, seed yield and oil content in the present study except at E_1 (Table2 and Table 3). From the pooled analysis of variance, it was seen that individual environmental effects were highly significant for all the characters indicating differential effect of each environment. The genotype x environment interaction was significant for all the traits. These results indicated the differential response of the genotypes when grown under different environments, and the relative merits of different genotypes changed with environments. Hence, the data were subjected to different types of stability analyses.

Table 2 Analysis of variance for AMMI model for various characters in sesame

Source	df	Mean squares				
		Plant height (cm)	Number of branches/plant	Number of capsules/plant	Seed yield (kg/ha)	Oil content (%)
Treatment	54	952.30**	5.32**	2312.45**	47509.56**	24.67**
Genotype	10	671.05**	12.62**	3441.12**	77584.40**	22.76**
Environment	4	9692.85**	30.45**	16160.38**	94684.00**	205.21**
Genotype x Environment	40	148.55**	0.99**	645.49**	35273.40**	7.10**
IPCA 1	13	313.41**	2.11**	1051.81**	54144.26**	17.51**
IPCA 2	11	79.55**	0.80**	714.63**	36475.00**	3.49**
IPCA 3	9	75.04*	0.29	385.34**	22702.02**	1.17
Residual	7	31.05	0.11	116.73	14502.49**	1.06
Error	54	29.30	0.27	42.13	1425.78	0.74

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

The model for joint regression analysis (Eberhart and Russell, 1966) was applied to get information on the individual genotype stability and adaptability. This model assumes that the genotype x environment interaction is predominantly linear in function of the environmental mean. They defined both linear and non-linear function of the genotype x environment interaction in which genotype x environment sum of squares is partitioned into i) linear components of environment, ii) linear components of genotype x environment interaction and iii) deviation from regression. In this investigation, such analysis for all the characters studied, indicated the presence of significance for linearity for environment and genotype x environment interaction. This implied the assumption for the differences among the linear response of genotypes to environment is valid. However, the pooled deviation from regression was also significant when tested against the pooled error, there by indicating the presence of non-linearity for all the characters. When the variance of the genotype x environment (linear) and the pooled deviations were compared, it was observed that the magnitude of the pooled deviation was more than the genotype x environment (linear) variance for all the characters except oil content. This indicated that the non-linear response of genotypes was more than the linear response. The oil content recorded greater magnitude of linear response than non-linear response. Henry and Daulay (1987) and Mahdy and Bakheit (1988) reported that both linear and non-linear components were significant for seed yield. Kulkarni *et al.* (1991) reported preponderance of non-linear component for seed yield. Suresh *et al.* (1991) and Ganesh (1996) reported preponderance of linear component for seed yield. In this model, the use of squared deviation from regression (S^2d) is considered as the main criterion for assessing the stability of individual genotypes. Bilbro and Ray (1976) also believed that a logical parameter for stability would be one that measures the dispersion around the regression line and it would be related to the predictability and repeatability of performance in different environments. In the present investigation, among all genotypes studied, the hybrid SO 573 x IS 534 and the varieties CO 1 and TMV 4 recorded non-significant deviation from regression (S^2d) for seed yield. Apart from this, three genotypes also recorded regression values nearing unity (b=1; not significant). This confirmed that these three genotypes had higher

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Stability of sesame (*Sesamum indicum* L.) hybrids in multilocation trials

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Abstract

Eight high yielding hybrids and three check cultivars were tested at five locations to assess their relative performance. The results revealed that hybrids SI 861 x SI 2257, SI 861 x BS 6-1-1, IS 200 x IS 305 and SI 2257 x SO 573 had high mean performance for seed yield. All these hybrids recorded more than 65 % standard heterosis. The high yielding hybrids showed inconsistency in stability under different models of stability analysis. Hence, considering the over all performance, three hybrids SI 861 x BS 6-1-1, IS 200 x IS 305 and SI 2257 x SO 573 were recommended for cultivation to realize the hybrid vigour for seed yield and component characters.

Key words : Sesame, hybrids, G x E interaction, stability, seed yield

Introduction

In India the sesame (*Sesamum indicum* L.) productivity is very low as it is grown mostly under rainfed conditions on infertile lands. Varietal improvement of sesame during the past had been oriented towards developing pure line varieties through conventional breeding. In recent years, developing hybrids through heterosis breeding is being attempted. The genotype x environment interaction plays an important role in the performance of genotypes. Hence, a multilocation evaluation of eight high yielding hybrids along with local cultivars was done to assess their relative performance.

Materials and methods

The experiment was conducted at Faculty of Agriculture, Annamalai University, Annamalainagar during *kharif*, 1997. Eight high yielding hybrids viz., SI 861 x SI 2257, SI 861 x BS 6-1-1, SI 861 x IS 207, SI 2257 x S 0573, SI 2257 x IS 305, S 0573 x IS 207, S 0573 x IS 534 and IS 200 x IS 305 were compared with three check varieties namely TMV 3, TMV 4 and CO 1 at five locations *viz.*, Nallampalli (E_1), Palacode (E_2) and Pauparappatti (E_3) of Dharmapuri district and Annamalainagar (E_4) and Vriddhachalam (E_5) of Cuddalore district of Tamil Nadu. The trial was conducted in randomized block design replicated twice with a plot size of 12 m^2 with a spacing of 45x20 cm. Recommended cultural practices were followed. Observations were recorded on plant height, number of branches per plant, number of capsules per plant, seed yield per plant and oil content. The data were subjected to location wise analysis of variance and pooled analysis as suggested by Panse and Sukhatme (1976). Since, the variance due to genotype x environment interaction was found significant, stability analysis was carried out (Table 1). Five stability parameters namely stability factor (Lewis, 1954), squared deviation from regression (Eberhart and Russell, 1966), stability variance (Shukla, 1972) coefficient of variation (Francis and Kannenberg, 1978) and IPCA scores from additive main effects and multiplicative interaction model (Gauch, 1985) were calculated.

Table 1 Analysis of variance over environments for various characters in sesame

Source	df	Mean squares				
		Plant height (cm)	Number of branches/plant	Number of capsules/plant	Seed yield (kg/ha)	Oil content (%)
Environment	4	9692.84**	30.45**	16160.45**	94680.50**	205.58**
Genotypes	10	671.06**	12.61**	3441.11**	77585.00**	22.84**
Genotype x Environment	40	148.55**	0.99**	645.49**	35273.90**	7.08**
Pooled error	50	28.55	0.27	39.27	1483.62	0.59

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

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Number of capsules/plant

SI 861 x SI 2257	103.4b	1.26±0.26	177.3**	33.1	39.95**	3.22
SI 861 x BS 6-1-1	78.4c	0.55±0.19	83.9**	21.9	17.10**	1.58
SI 861 x IS 207	98.5b	1.38±0.31	255.2**	38.9	58.98**	3.18
SI 2257 x S 0573	106.3a	1.14±0.27	188.5**	30.1	42.68**	2.73
SI 2257 x IS 305	117.6a	1.09*±0.68	1319.2**	35.0	319.07**	2.14
S 0573 x IS 207	110.9a	0.68±0.39	433.7**	24.4	102.61**	1.86
S 0573 x IS 534	96.3b	1.09±0.43	527.7**	35.2	125.60**	2.24
IS 200 x IS 305	109.3a	1.15±0.30	248.0**	29.8	57.23**	1.85
TMV 3	69.7c	0.85±0.15	44.5**	32.9	7.48	2.26
CO 1	70.7c	0.97±0.15	50.1**	36.9	8.86	2.56
TMV 4	67.1c	0.85±0.24	145.4**	37.0	32.15**	2.17

Grand mean = 93.5, CD (P=0.05) = 12.28, Mean (CV) = 2.1

Seed yield (kg/ha)

SI 861 x SI 2257	907a	1.69**±1.19	23544.5**	33.9	5523.34**	1.88
SI 861 x BS 6-1-1	921a	0.78±1.39	32655.2**	31.7	7750.45**	1.20
SI 861 x IS 207	799b	1.47**+0.98	15693.0**	33.0	3604.12**	1.47
SI 2257 x S 0573	852b	-0.82*±1.18	23046.2**	30.6	5401.59**	0.98
SI 2257 x IS 305	751b	0.25±1.39	32714.5**	39.0	7764.94**	1.62
S 0573 x IS 207	820b	2.13**±1.31	28761.1**	43.6	6798.51**	1.60
S 0573 x IS 534	722b	1.81±0.19	-120.7	29.4	-261.46	2.13
IS 200 x IS 305	909a	1.99**+0.81	10413.1**	30.9	2313.47**	2.23
TMV 3	524c	0.86**±0.73	8396.8**	35.2	1820.61**	1.24
CO 1	515c	0.83±0.24	281.5	23.8	-163.11	1.92
TMV 4	501c	0.01±0.43	242.5	18.3	360.85	1.09

Grand mean = 747, CD (P=0.05) = 140, Mean (CV) = 31.8

Oil content (%)

SI 861 x SI 2257	47.68b	0.94±0.14	0.46	6.2	0.1586	1.18
SI 861 x BS 6-1-1	44.15c	0.50±0.39	5.41**	5.51	1.3671**	0.13
SI 861 x IS 207	48.48b	1.45±0.16	0.64*	8.89	0.2025*	1.23
SI 2257 x S 0573	47.07b	1.34±0.12	0.24	8.4	0.1051	1.23
SI 2257 x IS 305	46.65b	0.61±0.04	-0.24	3.91	-0.0127	1.11
S 0573 x IS 207	48.47b	1.15±0.06	-0.18	6.92	0.0027	1.19
S 0573 x IS 534	49.03b	0.56±0.08	-0.05	3.97	0.0339	1.09
IS 200 x IS 305	48.61b	0.87±0.14	0.48	5.43	0.1626*	1.15
TMV 3	47.20b	2.28**±0.18	0.93*	14.08	0.2724**	1.47
CO 1	48.85b	0.72±0.09	-0.01	4.43	0.0432	1.1
TMV 4	49.56a	0.57±0.17	0.79*	4.14	0.2384*	1.5

Grand mean = 4.78, CD (P=0.05) = 1.49, Mean (CV) = 6.53

a : significantly superior over experimental mean; b : significantly equal to experimental mean
c : significantly below the experimental mean; x, xx : significant at 5 and 1% level from error variance

stability with average responsiveness to environments. Considering the mean performance for seed yield, the hybrids SI 861 x SI 2257, SI 861 x BS 6-1-1, IS 200 x IS 305 and SI 2257 x SO 573 recorded superior yield of more than 65% standard heterosis. However these hybrids recorded significant S^2d values and are hence unstable. The hybrid SI 861 x BS 6-1-1 recorded stability over environment (non significant S^2d) for plant height and number of branches per plant and the hybrid IS 200 x IS 305 showed stability for plant height, number of branches per plant and oil content. The hybrid SI 2257 x SO 573 expressed stability for number of branches per plant and oil content. The hybrid SI 861 x SI 2257 showed stability for number of branches/plant and oil content and hybrid SO 573 x IS 534 and variety CO1 for number of branches per plant and oil content besides yield.

***Table 3* Stability parameters of genotypes of sesame**

Genotype	Mean over environments	bi±S.E.	S^2d	C.V. (%)	Stability variance	Stability factor (S.F.)
			Plant height (cm)			
SI 861 x SI 2257	113.2b	1.13±0.37	231.0**	23.0	58.03**	1.84
SI 861 x BS 6-1-1	94.7b	1.25±0.14	19.8	26.8	6.41	2.34
SI 861 x IS 207	108.9b	1.03±0.14	19.7	19.6	6.38	1.72
SI 2257 x S 0573	111.7b	0.94±0.16	30.8*	18.1	9.09*	1.71
SI 2257 x IS 305	111.9b	0.81±0.12	10.6	15.3	4.15	1.55
S 0573 x IS 207	108.7b	0.90±0.11	5.3	16.7	2.87	1.60
S 0573 x IS 534	97.3b	1.08±0.23	75.5**	23.7	20.01*	1.91
IS 200 x IS 305	94.1b	1.17±0.09	0.2	25.3	1.61	2.19
TMV 3	101.7b	0.98±0.29	136.4**	21.8	34.91**	1.78
CO 1	94.6b	0.89±0.15	27.7*	20.1	8.34*	1.68
TMV 4	93.4b	0.82±0.31	151.1**	21.4	38.51**	1.65
Grand mean = 102.7, CD (P=0.05) = 10.5, Mean (CV) = 21.1						
			Number of branches/plant			
SI 861 x SI 2257	5.3b	1.28±0.19	0.06	28.7	0.04	1.91
SI 861 x BS 6-1-1	5.3b	0.64±0.15	-0.01	16.3	0.02	1.25
SI 861 x IS 207	5.9b	1.19±0.28	0.29*	24.6	0.09*	1.76
SI 2257 x S 0573	5.6b	1.16±0.21	0.11	25.0	0.05	1.61
SI 2257 x IS 305	6.4b	1.48*±0.65	2.24**	33.3	0.57**	1.33
S 0573 x IS 207	6.4b	0.93±0.35	0.52**	19.1	0.15**	1.65
S 0573 x IS 534	6.7a	0.92±0.19	0.07	17.4	0.04	1.47
IS 200 x IS 305	7.4a	1.17±0.19	0.07	19.7	0.04	1.61
TMV 3	4.1c	0.92±0.17	0.02	27.4	0.03	1.67
CO 1	4.3c	0.75±0.16	0.01	23.2	0.02	1.35
TMV 4	3.9c	0.57±0.27	0.27*	21.9	0.09*	1.56
Grand mean = 5.6, CD (P=0.05) = 1, Mean (CV) = 23.3						

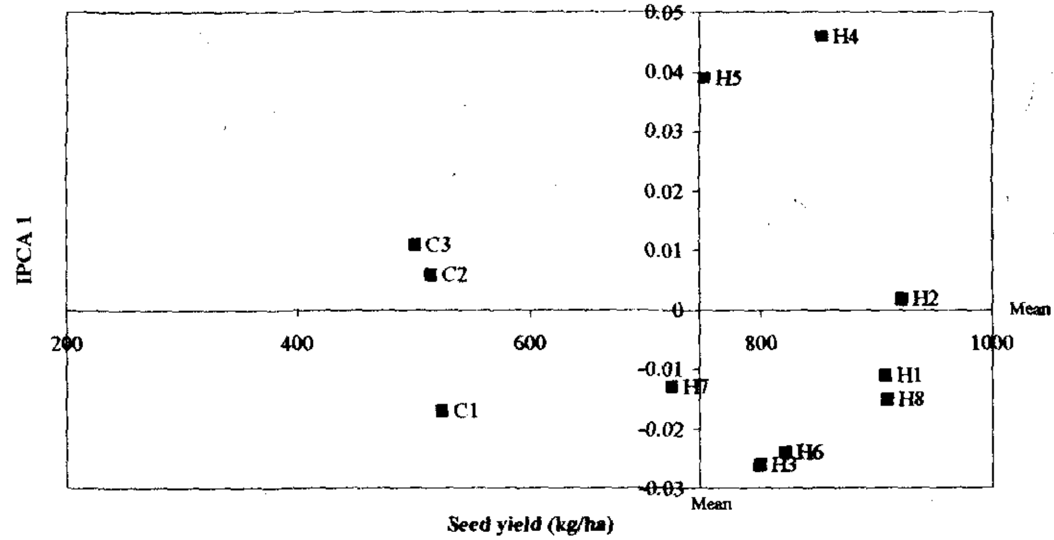

Fig. 1. Biplot graph of AMMI for seed yield

H1	SI 861 X SI 2257	H7	SO 573 X IS 534
H2	SI 861 X BS 6-1-1	H8	IS 200 X IS 305
H3	SI 861 X IS 207	C1	TM V 3
H4	SI 2257 X SO 573	C2	CO 1
H5	SI 2257 X IS 305	C3	TMV 4
H6	SO 573 X IS 207		

IS 534 and IS 200 x IS 305 for number of branches per plant; SI 861 x SI 2257, SI 2257 x SO 573, SO 573 x IS 207 and IS 200 x IS 305 for number of capsules per plant and SO 573 x IS 207, IS 200 x IS 305 and CO 1 for oil content were adjudged as stable hybrids with high mean performance and less interaction. Considering all the characters together, IS 200 x IS 305 and SI 861 x SI 2257 were highly stable for seed yield, number of capsules per plant and oil content and the hybrid SI 2257 x SO 573 had stability for plant height and number of capsules per plant.

According to Lin *et al.* (1986), the stability variance (Shukla, 1972) is a relative measure depending on the genotypes involved in the study, so its scope of influence is confined to the genotypes studied and should not be generalized. In joint regression analysis of Eberhart and Russell (1966), the stability of genotype is defined by the magnitude of predictable part (regression) to the unpredictable part (deviation MS). Though this method received a wide acceptance, it is doubtful if the deviation MS from regression does represent stability character of the genotype. Vanniyarajan *et al.* (1997) also reported that *per se* and S^2d values had high negative correlation in red gram and the chance of getting high yielding stable genotype based on Eberhart and Russell (1966) is remote. Moreover the stability obtained from these two models namely S^2d and stability variance differed with other models. Hence these two models were not considered for deciding stability status of the hybrids.

While selecting a genotype for recommendation over different locations, the maximum average performance of a genotype should be given importance followed by stability of performance. Based on the results of the present investigation, it was observed that the hybrids SI 861 x SI 2257, SI 861 x BS 6-1-1, IS 200 x IS 305 and SI 2257 x SO 573 had high mean performance for seed yield. All these recorded more than 65 per cent standard heterosis. Among these three hybrids IS 200 x IS 305 also had high mean performance for number of branches per plant as well as number of capsules per plant and SI 2257 x SO 573 for number of capsules per plant. While considering the stability parameters provided by the different models discussed above, it was observed that the hybrid SO 573 x IS 534 is highly stable over environments but it registered lowest yield of 722 kg/ha and hence not recommended. The high yielding four hybrids showed inconsistency in the stability status under different model of stability analysis.

The hybrid SI 861 x BS 6-1-1 showed stability for plant height and number of branches per plant by Eberhart and Russell and also by Shukla models; for number of branches per plant, seed yield and oil content by stability factor; for seed yield by genotype grouping technique and also by AMMI model (Table 4). The hybrid IS 200 x IS 305 recorded stability for plant height, number of branches per plant and oil content by Eberhart and Russell model; for plant height and number of capsules per plant by Shukla

Shukla's (1972) stability variance parameters ($\sigma^2 i$ and $S^2 i$) is a measure of unbiased partitioning of the total variation due to genotype x environment interaction into components assignable to individual cultivars led to the following conclusions. The hybrid SO 573 x IS 534 and varieties CO1 and TMV 4 recorded non-significant adjusted stability variance for seed yield. Similarly, the hybrids SI 861 x BS 6-1-1, SI 861 x IS 207, SI 2257 x IS 305, SO 573 x IS 207 and IS 200 x IS 305 for plant height; SI 861 x SI 2257, SI 861 x BS 6-1-1, SI 2257 x SO 573, SO 573 x IS 534, IS 200 x IS 305, TMV 3 and CO1 for number of branches per plant; CO1 and TMV 4 for number of capsules per plant and SI 861 x SI 2257, SI 2257 x SO 573, SI 2257 x IS 305, SO 573 x IS 207, SO 573 x IS 534 and CO1 for oil content were found stable. Considering all the characters together the hybrid SO 573 x IS 534 and variety CO1 were stable for seed yield, number of branches per plant and oil content. Though hybrid IS 200 x IS 305 and SI 2257 x BS 6-1-1 recorded stability for plant height and number of branches; the hybrid SI 2257 x SO 573 for number of branches per plant and oil content, these hybrids showed instability for seed yield.

Francis and Kannenberg (1978) proposed a method for grouping genotypes on the basis of mean performance and consistency of performance. They also suggested that a stable genotype should have consistent performance over environments. The consistent performance means a genotype that has low coefficient of variation. In the present study, the genotypes were grouped into i) high mean with low variation, ii) high mean with high variation, iii) low mean with low variation and iv) low mean with high variation. The genotypes that were classified under group I had more consistency with higher mean performance. According to this type of analysis, the hybrids SI 861 x BS 6-1-1, SI 2257 x SO 573 and IS 200 x IS 305 had stability for seed yield with high mean performance. Though the hybrid SO 573 x IS 534 and variety CO 1 recorded low variation, it recorded low mean seed yield and these were not considered as stable as per this model. The hybrids SI 861 x IS 207, SI 2257 x SO 573, SI 2257 x IS 305 and SO 573 x IS 207 for plant height; SO 573 x IS 207, SO 573 x IS 534 and IS 200 x IS 305 for number of branches per plant; SI 2257 x SO 573, SO 573 x IS 207 and IS 200 x IS 305 for number of capsules per plant and SO 573 x IS 534, IS 200 x IS 305, CO 1 and TMV 4 for oil content recorded high mean performance with low coefficient of variation. Considering all the characters together, the hybrid IS 200 x IS 305 is adjudged as the best since it had high mean performance with consistency for seed yield, number of branches per plant, number of capsules per plant and oil content. Further, the hybrid SI 2257 x SO 573 can also be considered since it showed stability for seed yield, plant height and number of capsules per plant.

The next criterion for identifying a genotype with less fluctuation in yield is by measuring the ratio between the mean yield of high yielding environment and the low yielding environment which is termed as stability factor by Lewis (1954). The stability factor nearing a ratio of 1.00 indicated the maximum phenotypic stability. It was observed that SI 861 x BS 6-1-1, SI 2257 x SO 573, TMV 3 and TMV 4 recorded a near unity ratio of stability factor for seed yield. The hybrids SO 573 x IS 534, IS 200 x IS 305 and CO 1 recorded higher ratio (above 1) of stability factor. The genotypes with favorable stability factor (nearer to 1) identified were SI 2257 x IS 305 and SO 573 x IS 207 for plant height; SI 861 x BS 6-1-1, SI 2257 x IS 305, and CO 1 for number of branches per plant; SI 861 x BS 6-1-1, SO 573 x IS 207 and IS 200 x IS 305 for number of capsules per plant and SI 861 x BS 6-1-1, SI 2257 x IS 305, SO 573 x IS 534, CO 1 and TMV 4 for oil content. Considering all the characters together, the hybrid SI 861 x BS 6-1-1 was considered as more stable than other hybrids.

Increasing the accuracy of estimating crop yields involved three fundamentally different but complementary strategies namely better experimental techniques, analysis of experimental designs (within environment information involving replication and blocking) and analysis of treatment designs (between environment information including interaction). The first two options have been exploited extensively, but the third option was neglected almost completely. For the third option, the additive main effects and multiplicative interaction effects (AMMI) model is an effective one for estimation.

The AMMI analysis for seed yield (Table 2) indicated that first IPCA axis of the interaction captured 49.9 % of the interaction SS and the second and third IPCA axis accounted for 28.4 and 14.4 % of the interaction SS respectively. The total of the IPCA axis accounted for 92.8% of the variation of the interaction, while the residual SS accounted for 7.2 % of the interaction SS. This fact suggested the effectiveness of the model in describing the genotype and environment interaction. The AMMI model effectively explored in the underlying interaction pattern in the multilocation yield trials as reported by Zobel *et al.* (1988).

In the biplot presentation, if a genotype or environment has a IPCA score of nearly zero it has small interaction effects and hence can be fitted well by an additive model (Zobel *et al.*, 1988). The hybrid SI 861 x SI 2257, SI 861 x BS 6-1-1 and IS 200 x IS 305 exhibited very low interaction with high yield potential (Fig. 1). The SI 2257 x SO 573 showed high interaction for seed yield. Similarly the hybrids SI 861 x IS 207, SI 2257 x SO 573, SI 2257 x IS 305 and SO 573 x IS 207 for plant height; SO 573 x

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Estimation of additive, dominance and digenic epistatic interaction effects for yield and its components in linseed (*Linum usitatissimum* L.)

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Abstract

Main gene effects and epistatic gene effects were estimated for yield and its components in four crosses of linseed (*Linum usitatissimum* L.) by partitioning the generation means. None of the characters showed exact fit of three parameter model in all the four crosses. The relative comparison of main gene effects revealed major contribution of dominance effects associated with *dd* type of interaction effects in the expression of all the characters of all the crosses. Duplicate type of epistatis played a major role in expression of the characters studied in the crosses.

Key words : Allelic, non-allelic interactions, linseed

Introduction

The suitability of generation means technique is the understanding the role of epistatic interaction in the expression of yield and its components, that will be helpful in the genetic improvement of linseed. In comparison to the other methods available for understanding the epistatic interactions, the partitioning of generation means was found to be the best in different crop plants. The present study was planned to estimate the nature and magnitude of allelic and non-allelic interactions in linseed.

Materials and methods

The experimental material comprised five divergent genotypes of linseed. These were crossed among themselves to develop F_1, F_2, BC_1 and BC_2 generations. The crosses were R-552 x RLC-29, R-552 x Kiran, Kiran x RLC-29 and LCK-9019 x Acc.926. The experiment was laidout in randomized compact family blocks with four replications. Randomization was carried out among the four crosses and also populations within a cross. Six populations namely P_1, P_2, F_1, F_2, BC_1 and BC_2 of four crosses were planted in continuous lines of a replication. The parents and non-segregating populations were grown in single rows whereas, F_2 was grown in twelve rows with the row length of three meters. The row to row distance of 30 cm, intra row distance of 5 cm was maintained. Well grown, competitive five plants randomly tagged for parents, F_1s and back crosses and 36 plants randomly from F_2s were selected from six rows of each entry for all the characters of four crosses to record observations on days to flower, days to maturity, plant height, primary and secondary branches/plant, number of effective capsules/plant, number of unfilled capsules per plant, dry plant weight, 100-seed weight, number of seeds per plant and seed yield per plant. Three parameter model was fitted by using weighted least mean square technique as suggested by Cavalli (1952). The validity of this model was tested by χ^2 test. Wherever three parameter model was found inadequate, five parameter model was fitted.

Results and discussion

Gene effects for all eleven characters of the four crosses have been given in Table 1-4. For the cross R-552 x RLC-29 additive x dominance gene effects were significant for days to flower initiation, number of effective capsules, dry plant weight and grain yield. However, in this cross relatively dominance effects were greater for almost all the characters under study. For days to flower initiation, additive x additive and dominance x dominance gene effects were significant. Duplicate type of epistasis was observed for all the characters except plant height. Whereas additive effects were significant for days to flower initiation, number of primary branches, number of capsules, dry plant weight and grain yield. Among non-allelic interaction effects additive x additive was significant for almost all traits except plant height, 100-seed weight and grain yield.

The additive gene effects and additive x additive or any digenic complementary gene interaction was fixable and useful. In this population these effects could be exploited for improvement of days to flower initiation i.e., for early types.

model; for number of capsules per plant by stability factor; for number of branches per plant, number of capsule per plant, seed yield and oil content by genotype grouping method; for number of branches per plant, number of capsules per plant, seed yield and oil content by AMMI model. The hybrid SI 2257 x SO 573 had stability for number of branches per plant and oil content by Eberhart and Russell and stability variance models; for seed yield by stability factor method; for plant height, number of capsules per plant and seed yield by genotype grouping technique and for plant height and number of capsules per plant by AMMI model. Considering the over all performance, these three hybrids SI 861 x BS 6-1-1, IS 200 x IS 305 and SI 2257 x SO 573 should be recommended for cultivation to realize the hybrid vigour for seed yield.

Table 4 List of stable sesame hybrids for various characters

Code	Hybrid/variety	Character	Existence of stability through various models
H2	SI 861 x BS 6-1-1	Number of capsules/plant	Stability factor
		Seed yield	Stability factors, genotype grouping technique, AMMI
		Oil content	Stability factors
H4	SI 2257 x SO 573	Number of capsules/plant	Genotype grouping technique, AMMI
		Seed yield	Stability factor, genotype grouping technique
		Oil content	Eberhart and Russell, stability variance
H8	IS 200 x IS 305	Number of capsules/plant	Stability factor, genotype grouping technique, AMMI
		Seed yield	Genotype grouping technique, AMMI
		Oil content	Eberhart and Russell, genotype grouping technique, AMMI

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In the cross R-552 x Kiran, both additive and dominance gene effects were significant for number of primary branches per plant. Dominance x dominance gene effects were significant for all the characters under study.

Additive gene effects and additive x dominance gene effects were significant for days to maturity and additive gene effects were significant for plant height. Dominance, additive x additive gene effects were significant for plant height and primary branches per plant. Dominance, additive x additive and additive x dominance gene effects were significant for number of seeds per plant and grain yield per plant. All the characters were governed by the duplicate type of gene interaction except 100-seed weight. Further, improvement of these crosses could be possible in the later generations.

In cross, Kiran x RLC-29, additive and additive x dominance gene effects were significant for days to flower initiation and days to maturity. Dominance gene effects and additive x additive gene effects were significant for days to flower initiation and plant height. Dominance gene effects were also significant for days to maturity, number of capsules, dry plant weight, number of seeds per plant and grain yield. Duplicate type epistasis was observed for all the characters in these crosses barring 100-seed weight, where a complementary type of epistasis was observed. Perusal of additive, dominance, epistatic gene effect, additive and dominance variances indicated that the selection criteria in the early generations of this cross will not solve the purpose of improvement in the seed yield.

Table 3 Estimates of gene effects and their standard error of Kiran x RLC-29 cross of linseed for yield and its components

Character	m	d	h	i	j	l	χ^2	Type of epistasis
Days to flower initiation	52.59±0.21**	-1.50±0.46*	3.58±1.40*	2.63±1.25*	-1.34±0.51*	-5.73±2.40*	10.57	D
Days to maturity	101.20±0.24**	-2.70±0.82*	-20.40±2.14**	-22.60±1.92**	-4.75±1.01*	37.00±3.94*	150.77	D
Plant height (cm)	58.94±0.61**	-3.39±2.07	12.37±5.11	10.82±4.82*	-1.64±2.60	-14.22±9.29	6.58	D
Number of primary branches/plant	4.90±0.15*	0.34±0.67	-2.13±1.56	-2.33±1.48	0.64±0.74	4.83±2.90	2.73	D
Number of secondary branches/plant	15.18±0.58**	-2.65±2.58	2.37±5.78	2.95±5.78	-2.02±2.74	-70.30±10.83	0.82	D
Number of effective capsules/plant	140.16±8.10**	-23.85±16.72	-208.64±47.29*	-244.16±46.58*	-16.07±18.14	344.0±76.09*	40.10	D
Number of unfilled capsules/plant	15.11±1.08**	-0.40±1.89	21.49±7.60*	-29.04±5.76**	1.10±2.11	58.14±13.22*	29.20	D
Dry plant weight (g)	29.27±1.17**	-3.25±2.06	-30.06±6.35*	-34.78±6.26*	-2.57±2.24	47.43±9.74*	43.20	D
100-seed weight (g)	0.66±0.005	-0.02±0.01*	-0.30±0.29*	0.29±0.032**	0.71±0.020	-0.80±0.08**	164.00	C
Number of seeds/plant	891.18±48.69*	-154.10±130.08	-892.22±329.00*	-1177.75±325.0*	-87.72±138.70	1778.10±566.05	17.94	D
Seed yield/plant	6.10±0.32**	-0.86±0.81	-5.63±2.12*	-8.33±2.08*	0.37±0.88	15.34±3.60*	23.83	D

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

D = Duplicate type of epistasis; C = Complementary type of epistasis

Table 1 Estimates of gene effects and their standard error of R-552 x RLC-29 cross of linseed for yield and its components

Character	m	d	h	i	j	l	χ^2	Type of epistasis
Days to flower initiation	51.38±0.26**	-4.21±1.57**	4.21±1.57**	3.34±1.43*	-4.52±0.53**	-6.19±2.53*	87.46	D
Days to maturity	108.83±0.41**	1.05±1.09	-20.43±2.86**	-22.83±2.75**	0.40±1.21	32.33±4.94**	76.64	D
Plant height (cm)	61.15±0.62**	2.54±2.40	0.38±5.56	-3.73±5.41	1.52±2.64	1.18±10.25	3.37	C
Number of primary branches/plant	6.21±0.20**	-44.99±0.62**	-5.18±1.59*	-5.96±1.49**	-0.92±0.70	8.13±2.86**	18.74	D
Number of secondary branches/plant	21.28±0.96**	-2.09±1.66	-43.88±5.44**	-40.73±5.08*	-2.04±2.45	41.23±8.60**	78.91	D
Number of effective capsules/plant	121.56±6.41**	-28.35±13.14*	-149.45±37.42**	-190.95±36.85**	-33.65±14.37*	258.25±59.93**	365.49	D
Number of unfilled capsules/plant	21.47±1.39**	-4.50±1.78*	-40.16±8.70**	-40.81±6.61**	-1.00±2.25	62.41±14.49*	40.26	D
Dry plant weight (g)	16.68±0.79**	-4.45±1.54*	-4.83±4.50	-14.42±4.42**	-5.07±1.67**	25.20±7.15**	28.00	D
100-seed weight (g)	0.76±8.11	0.21±0.30	0.59±0.61	0.43±0.61	0.20±0.30	-0.82±1.26	1.51	D
Number of seeds/plant	795.20±42.91**	-158.0±98.74	-930.13±266.95**	-1254.43±261.66**	181.80±106.17	1887.43±441.28**	29.13	D
Seed yield/plant	60.37±0.36**	-1.68±0.74*	-6.50±2.12**	-1.09±2.08	1.86±0.80*	19.66±3.42**	45.50	D

*, ** Significant at 5% and 1% levels, respectively.
D = Duplicate type of epistasis; C = Complementary type of epistasis

Table 2 Estimates of gene effects and their standard error of R-552 x Kiran cross of linseed for yield and its components

Character	m	d	h	i	j	l	χ^2	Type of epistasis
Days to flower initiation	50.75±0.22**	0.45±0.57	11.64±1.54**	10.87±1.45**	-0.47±0.64	-10.12±2.69**	91.54	D
Days to maturity	100.65±0.39**	-4.59±0.83**	17.18±2.34**	13.18±2.57**	-9.64±0.95**	26.58±4.01**	157.52	D
Plant height (cm)	62.72±0.51**	-9.99±1.87**	-1.49±4.58	-3.71±4.27	1.02±2.22	16.46±8.22**	10.82	D
Number of primary branches/plant	5.48±0.49**	-0.50±0.40	-5.59±1.29**	-7.94±1.16**	-0.94±0.50	15.64±2.20**	53.35	D
Number of secondary branches/plant	17.43±0.79**	-2.75±1.26**	-19.07±4.26**	-25.05±4.06**	-3.82±1.62*	47.80±6.49**	83.61	D
Number of effective capsules/plant	117.81±6.18**	-16.65±11.39	-213.92±34.74**	-247.17±33.64**	-33.45±14.07*	446.37±54.67**	67.91	D
Number of unfilled capsules/plant	11.82±0.80**	-1.40±1.26	-13.55±4.47**	-22.10±4.10**	-2.80±1.52*	42.00±6.98**	47.34	D
Dry plant weight (g)	17.51±0.75**	-2.95±1.26*	-21.73±4.07**	26.95±3.93	-3.92±1.43**	46.60±6.23**	60.05	D
100-seed weight (g)	0.64±0.0072	-0.026±0.023	0.15±0.056**	-0.019±0.054	-0.044±0.024	0.34±0.10*	116.24	C
Number of seeds/plant	729.28±38.26**	-93.0±79.55	-1150.0±229.88**	-1335.53±220.78**	164.95±91.36	254.43±375.63*	48.50	D
Seed yield/plant	4.88±0.26**	-0.35±0.56	-6.09±1.63*	-9.08±1.55**	-1.04±0.63	20.62±2.70*	61.26	D

*, ** Significant at 5% and 1% levels, respectively.
D = Duplicate type of epistasis; C = Complementary type of epistasis

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Exploitation of heterosis using diverse sources of cytoplasm in sunflower

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Abstract

In spite of development of diverse cytoplasmic male sterile systems, only a single source of cytoplasm (PET-1) has been exploited for hybrid seed production in sunflower. In the present study diverse cytoplasmic male sterile sources based on PET-1, GIG-1 and PET-2 were utilized to study the extent of heterosis. Crosses were made between three different Cms lines and the newly identified restorers. The F_1 hybrids were evaluated for the extent of heterosis. All the newly developed hybrids exhibited significant heterosis in the desired direction for days to 50 % flowering and days to maturity over MSFH-17.The hybrid DCMS-6 x DRS-3 exhibited positive significant heterosis for seed yield per plant over KBSH-1 with a range of 22.33 to 56.79 %. The cross DCMS-1 x DRS-2 recorded significant heterosis over all the three checks for the trait oil percentage.

Key words : Sunflower, cytoplasmic male sterility, fertility restoration, heterosis and heterobeltiosis.

Introduction

Commercial cultivation of sunflower was started in India during 1972 with the introduction of four open pollinated varieties. Sunflower, being a cross pollinated crop, offers a scope for exploitation of heterosis. The discovery of cytoplasmic sterility in sunflower by Leclercq (1969) and subsequent identification of genes for fertility restoration (Kinman, 1970; Leclercq, 1972; Enns, 1972) have facilitated commercial hybrid seed production. Heterosis breeding initiated in mid seventies in India, resulted in the development and release of several high yielding hybrids.

All the presently grown commercial hybrids through out the world without exception, possess the PET-1 cytoplasm. The potential risk of the cytoplasm becoming vulnerable to any pest or disease has been identified in other crops like maize and *bajra*. Considering this fact diverse cytoplasmic male sterile systems like CMS PF, CMS I, CMS GIG-1, CMS PET-2, etc., were developed from different wild species. However, commercial exploitation of these sources has not become a reality due to lack of effective fertility restorers for these alternative sources of cytoplasm. In the light of above facts the present investigation was undertaken to study the extent of heterosis using diverse cytoplasmic sources and their effective restorers.

Materials and methods

The experimental material comprised of three diverse cytoplasmic male sterile sources *viz.*, PET-1, GIG-1, PET-2 and their newly identified restorer lines *viz.*, DRS-5, DRS-3 and DRS-2. All the three restorers were developed from the *Helianthus argophyllus*, a wild relative of the cultivated sunflower. The Cms lines used and their respective fertility restorers are presented in the following table:

Cms	Cytoplasmic source	Restorer line
CMS 7-1A	*Helianthus petiolaris* (PET-1)	DRS-5
DCMS-1	*Helianthus giganteus* (GIG-1)	DRS-2
DCMS-6	*Helianthus petiolaris* (PET-2)	DRS-2 and DRS-3

Crosses were made during *kharif*, 1998 between CMS lines and their respective fertility restorers. In the following *rabi* season six parents and four hybrids were raised along with three hybrids checks (KBSH-1, MSFH-17 and PAC-36) in a replicated block design. Data were recorded on nine different traits and subjected to statistical analysis.

Results and discussion

The mean values and the extent of heterosis were presented in table 1 and 2, respectively. The cross DCMS-6 x DRS-3 recorded highest mean values for head diameter, 100-seed weight and seed yield per plant (16.71 cm, 4.36 g and 41.08 g, respectively). Days to maturity was lowest in the case of DCMS-6 x DRS-3 (84 days) and rest all are on par with each other. DCMS-1 x DRS-2 recorded highest mean oil percentage of 43.67 followed by CMS 7-1A x DRS-5 (39.13%).

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Table 4 Estimates of gene effects and their standard error of LCK-9209 x Acc. 926 cross of linseed for yield and its components

Character	m	d	h	i	j	l	χ^2	Type of epistasis
Days to flower initiation	62.02±0.33**	-3.75±0.83**	-9.20±2.22**	-11.18±2.14**	-2.52±0.92**	8.93±3.78*	65.09	D
Days to maturity	115.29±0.51**	-10.65±0.89**	-4.51±2.85	-4.29±2.73	-8.97±1.05**	-13.35±4.44**	174.14	C
Plant height (cm)	73.17±0.76**	10.50±2.03**	5.28±5.27	-7.49±5.08	11.32±2.26**	31.94±9.13**	47.33	C
Number of primary branches/plant *	65.41±0.23**	-0.34±0.58	-2.56±1.70	-7.26±1.50*	-0.19±0.78	17.18±2.99*	35.33	D
Number of secondary branches/plant	22.42±0.93**	2.20±1.76	-31.79±5.33**	-40.09±5.12**	-2.70±1.99*	55.69±8.48**	61.82	D
Number of effective capsules/plant	163.00±9.20*	36.85±18.26*	-22.15±52.27	-32.32±51.85	29.62±19.19	-46.72±82.86	11.67	D
Number of unfilled capsules/plant	15.32±1.06**	-0.70±3.04	-1.68±7.70	-9.30±7.45	3.57±3.41	28.65±13.51*	9.44	D
Dry plant weight (g)	23.72±1.15**	8.70±2.19**	1.31±6.71	-0.88±6.37	11.35±2.96**	-7.71±10.79	24.88	D
100-seed weight (g)	*0.57±0.005*	*0.14±0.02**	*0.38±0.046***	*0.41±0.045***	*0.17±0.02*	*-0.78±0.084***	*153.99*	*D*
Number of seeds/plant	897.38±52.07**	32.65±99.22**	-650.49±292.96**	612.97±287.69*	324.42±110.11**	916.52±461.67*	11.22	D
Seed yield/plant	5.04±0.29**	3.62±0.66**	9.13±1.82**	6.24±1.77**	3.77±0.71*	-12.37±3.01**	39.82	D

*, ** Significant at 5% and 1% levels, respectively.
D = Duplicate type of epistasis; C = Complementary type of epistasis

In cross LCK-9209 x Acc.926, additive gene effects were significant for plant height, number of capsules, dry plant weight, 100-seed weight, number of seeds per plant and grain yield per plant.

Additive x additive, additive x dominance gene effects were significant for number of seeds per plant and grain yield per plant. Additive x dominance gene effects were significant for number of secondary branches and dry plant weight.

Additive and additive x dominance and dominance gene effects were significant for days to maturity, dominance gene effects were significant for days to flower initiation, *number of secondary branches per plant, 100-seed weight* and grain yield per plant.

The isolation of superior lines may be difficult in small populations of heterotic crosses in which the number of segregating loci with additive gene effects is relatively large. In these crosses it would be necessary to adopt the biparental crosses approach for accumulation of favouable and additive gene effect. These results are in agreement with Baker *et al.* (1972), Daucet (1978), Rao and Singh (1983), Tak (1996) and Foster *et al.* (1998).

An early generation selection pressure should also be applied for characters such as number of capsules per plant which exerted positive direct effects on yield.

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All the four hybrids showed positive significant heterobeltiosis and standard heterosis over any of the checks for more than one trait. The cross DCMS-6 x DRS-3 exhibited highest positive significant heterosis over KBSH-1 for head diameter (8.86%). The hybrid with its large head coupled with high self fertility is very useful for its commercial exploitation. All the new hybrids showed negative heterosis for days to 50 % flowering and days to maturity. Negative significant heterosis for days to maturity over all the checks was exhibited by the cross DCMS-6 x DRS-3, which showed the earliness of the new hybrid over the existing commercial hybrids and are expected to perform better, especially in North Western India where short duration hybrids are required to increase the area under sunflower cultivation as a second crop.

The cross DCMS-6 x DRS-3 recorded highest hetero-beltiosis (144.23%) and standard heterosis (56.79%) over KBSH-1 for seed yield per plant followed by the cross DCMS-6 x DRS-2 (124.33% and 38.28%, respectively). Only DCMS-1 x DRS-2 exhibited positive significant heterosis over better parent as well as the three checks for the trait oil per cent. Negative significant heterosis for days to 50 % flowering and days to maturity was reported by Kandhola *et al.* (1995). Positive significant heterosis for seed yield was reported by Chaudhary and Anand (1984) and Gangappa *et al.* (1997). Positive heterosis for oil percentage was reported by Pathak *et al.* (1983), Giriraj *et al.* (1986) and Gangappa et al. (1997).

All the new hybrids exhibited shorter duration compared to existing commercial hybrids. Highest positive heterosis for head diameter and seed yield per plant was recorded by DCMS-6 x DRS-3 followed by DCMS-6 x DRS-2 for the trait oil percentage, DCMS-1 x DRS-2 recorded positive significant heterosis for oil content over all the checks. When per hectare oil yield was taken into consideration, all the new hybrids tested were on par with each other. Thus, the new hybrids having diverse cytoplasmic backgrounds exhibited good agronomic performance. Such new hybrids are useful not only for exploitation of heterosis but also for widening the cytoplasmic base of the hybrids. Hence, these promising hybrids may be further tested for their performance over locations and seasons and if found stable can be utilized for commercial cultivation.

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Table 1 *Mean performance of parents and* F_1 **hybrids**

Source	Plant height (cm)	No. of leaves/ plant	Stem diameter (cm)	Days to 50% flowering	Head diameter (cm)	Days to maturity	Seed yield/plant (g)	Test weight (g)	Oil (%)
CMS 7-1 A	127.50	28.08	1.34	56.33	15.41	89.00	24.75	4.14	36.98
DCMS-6	123.50	27.41	1.67	55.33	14.48	87.00	11.80	4.06	34.03
DCMS-1	125.65	28.25	1.75	58.66	14.75	88.66	22.52	4.25	37.53
DRS-5	122.25	28.16	1.89	59.33	14.75	91.33	16.25	3.78	42.42
DRS-2	117.25	28.08	1.83	56.66	12.31	87.66	16.15	3.19	42.02
DRS-3	122.50	26.66	1.75	55.66	13.33	90.33	16.82	3.81	36.93
CMS 7-1 A x DRS-5	126.50	28.75	1.43	55.30	13.58	86.66	36.15	3.69	39.13
DCMS-6 x DRS-2	130.50	31.50	1.91	55.00	15.75	86.33	36.23	4.35	36.11
DCMS-6 x DRS-3	133.16	29.00	2.10	54.00	16.71	84.33	41.08	4.36	35.61
DCMS-1 x DRS-2	140.40	30.00	2.15	57.33	15.71	86.00	32.05	4.29	43.67
KBSH-1	129.50	29.33	1.88	57.00	15.35	87.33	26.20	4.28	39.66
MSFH 17	135.75	34.00	1.95	58.00	17.01	89.00	34.40	5.70	35.47
PAC 36	128.00	31.00	1.82	57.33	15.79	88.66	34.90	4.78	39.93
SEm±	1.00	0.57	0.03	0.44	0.27	0.45	0.83	0.07	0.22
CD	2.91	1.67	0.09	1.28	0.80	1.32	2.43	0.20	0.63

Table 2 Extent of heterobeltiosis and standard heterosis for different *characters*

Source	Plant height (cm)	No. of leaves/ plant	Stem diameter (cm)	Days to 50% flowering	Head diameter (cm)	Days to maturity	Seed yield/plant (g)	Test weight (g)	Oil (%)
CMS 7-1 A x DRS-5 Heterobeltiosis	-0.78	2.09	-24.33**	-1.83	2.21	-2.63*	46.06**	-10.87*	-7.75**
SH over KBSH 1	-2.14*	-1.98	-23.81**	-2.98	2.60	-0.77	37.97**	-13.78**	-1.34
SH over MSFH 17	-6.81**	-15.44**	-26.55**	-4.65*	-7.78**	-2.63*	5.08	-35.26**	10.32**
SH over PAC 36	-1.17	-7.25	-21.29**	-3.54	-0.25	-2.25	3.58	-22.80**	2.00
DCMS-6 x DRS-2 Heterobeltiosis	5.66**	12.18*	4.37	-0.59	8.77**	-0.77	124.33**	7.14	-14.07**
SH over KBSH 1	0.77	7.39	1.76	-3.51	2.60	-1.15	38.28**	1.64	-8.95**
SH over MSFH 17	-3.86**	-7.35	-1.90	-5.17**	-7.80**	-3.00*	5.32	-23.68**	1.80
SH over PAC 36	1.95	1.61	5.12	-4.06	-0.25	-2.63*	3.81	-8.99*	-9.56**
DCMS-6 x DRS-3 Heterobeltiosis	7.82	5.80	20.00**	-2.40	15.40**	-3.07*	144.23**	7.39	-3.57*
SH over KBSH 1	2.83*	-1.13	11.88**	-5.26**	8.86**	-3.43*	56.79**	1.87	-10.21**
SH over MSFH 17	-1.90	-14.70**	7.85	-8.62**	-2.18	-5.25**	19.42**	-23.50**	0.39
SH over PAC 36	4.03**	-6.45	15.57**	-5.81	5.82*	-4.88*	17.71**	-8.78*	-10.82**
DCMS-1 x DRS 2 Heterobeltiosis	11.74**	6.19	17.46**	1.18	6.51*	-1.89	42.32**	0.92	3.92**
SH over KBSH 1	8.42**	2.28	14.54**	0.58	2.34	-1.53	22.33**	0.23	10.11**
SH over MSFH 17	3.43**	-11.76**	10.43*	-1.15	-8.03**	-3.37*	-6.83	-24.73**	23.12**
SH over PAC 36	9.69**	-3.22	18.32**	0.00	-0.51	-3.00*	-8.16	-10.25**	9.36**

* Significant at 5% level; ** Significant at 1% level   SH : Standard heterosis

Table 1 Anova for combining ability in castor

Source	df	Days to 50% maturity of primary spike	100 seed weight (g)	No. of capsules on primary raceme	No. of nodes up to main spike	Total length of main spike (cm)	Effecgive length of main spike (cm)	Height up to primary raceme (cm)	No. of effective spikes per plant	Seed yield/ plant (g)
Replication	1	40.88*	2.21	1280.95**	11.86*	925.80**	834.04	1172.63**	0.521	1127.50
Treatment	46	28.63*8	44.41*8	502.41**	8.21**	144.21**	148.14	568.65**	2.18*	8543.59**
Parents	11	41.95*	89.71**	499.21	9.55	106.86	104.26	868.53**	3.71	3001.52
Parents vs. crosses	1	4.94	20.73*	3541.20**	46.69**	961.76**	1027.78	2260.06**	5.22*	22935.0**
Crosses	34	25.02	30.46**	414.07**	6.65**	132.25**	136.47	421.88**	1.60	9913.35**
Lines	4	37.23	58.77**	614.09	13.62**	185.80*	203.14	1162.95**	0.95	18173.88
Testers	6	24.48	96.50**	999.23**	16.67**	376.61**	377.30	829.76**	3.06	13972.17
Lines x Testers	24	23.11**	9.23*	234.44	2.98	62.23	65.15	196.40**	1.34	7521.87**
Error	46	6.61	5.13	145.03	2.55	49.69	50.06	79.38	1.28	1610.68
σ^2 line		1.01	3.54	27.12	0.76	8.83	9.86	69.04	-0.03	760.86
σ^2tester		0.14	8.73	76.48	1.37	31.44	31.22	63.34	0.17	645.03
σ^2(average)		0.06	0.62	5.27	0.11	2.05	2.09	6.61	0.01	70.09
$\sigma^2 sca$		8.25	2.05	44.71	0.22	6.27	7.55	58.51	0.03	2955.60
$\sigma^2 gca/\sigma^2 sca$		0.01	0.30	0.12	0.50	0.16	0.28	0.11	0.25	0.02

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

Table 2 General combining ability effects in castor

Source	Days to 50% maturity of primary spike	100 seed weight (g)	No. of capsules on primary raceme	No. of nodes up to main spike	Total length of main spike (cm)	Effective length of main spike (cm)	Height up to primary raceme (cm)	No. of effective spikes/ plant	Seed yield/ plant (g)
Lines									
JP- 78	0.49	2.34**	-4.83	-0.92*	-3.20	-3.64	-12.10	-0.31	-7.20
JP-81	1.06	-1.72**	8.03*	0.85*	5.09**	5.50**	13.40**	0.04	61.09**
JP-82	-1.09	-2.40**	4.17	-0.49	1.94	1.50	-2.24	-0.03	-25.85*
JP-83	-2.23**	0.19	-8.33**	-0.69	-3.63*	-3.50	-0.17	0.40	-0.84
SKP-4	1.77**	1.60**	0.96	1.26**	-0.20	0.14	1.11	-0.10	-27.20*
SE gi ±	0.69	0.61	3.22	0.43	1.88	1.89	2.38	0.30	10.73
SE (gi-gj)	*0.97*	*0.86*	*4.55*	*0.60*	2.66	2.67	3.37	0.43	15.17
CD (0.05)	1.35	1.19	6.31	0.84	3.69	3.71	4.67	0.59	21.02
CD (0.01)	1.77	1.56	8.29	1.10	4.85	4.87	6.13	0.78	27.63
Testers									
JI-122	-2.31**	-0.56	-3.16	-0.01	-2.11	-1.90	-5.27*	0.14	-23.47
JI-127	1.69*	-2.09**	0.24	-0.05	-0.11	0.20	2.33	-0.16	23.47**
JI-221	1.09	-1.42*	-6.06	-1.47**	-2.71	-2.80	-6.47*	0.04	0.58
JI-226	0.89	-1.51*	-6.16	-0.73	-4.91*	-4.60*	-7.87**	-0.46	-28.49**
JI-251	-0.01	6.81**	7.54*	1.09*	5.59*	5.30*	9.13**	-0.26	18.56**
JI-265	-2.01*	0.34	-10.86**	-1.07*	-6.51**	-7.0**	-6.97*	-0.46	-50.43**
DCS-47	0.69	-1.57*	*18.44***	*2.23***	*10.79***	*10.80***	*15.13***	*1.14***	*59.85***
SE gi ±	0.81	0.72	3.81	0.51	2.23	2.24	2.82	0.36	6.78
SE (gi-gj)	1.15	1.01	5.39	0.71	3.15	3.16	3.98	0.51	9.59
CD (0.05)	1.59	1.40	7.46	0.99	4.37	4.39	4.29	0.70	13.30
CD (0.01)	2.10	1.85	9.81	1.30	5.74	5.76	7.26	0.92	17.47

*,** Indicate significant at P = 0.05 and P = 0.01, respectively.

diversity among the females as compared to males for their combining ability. Higher magnitude of variances due to testers in comparison to lines were observed for 100 seed weight, number of capsules on primary raceme, number of nodes upto main spike, total length of main spike, effective length of main spike, height upto primary *raceme and number of effective spikes per plant.* The estimates of *sca* variances were considerably higher than *gca* (average) for all the characters studied, indicating preponderance of non-additive type of gene action in the inheritance of these traits. The results are in agreement with those of Patel *et al.* (1986); Dangaria *et al.* (1987); Dobaria *et al.* (1992) and Fatteh *et al.* (1998).

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Combining ability analysis in castor (*Ricinus communis* L.)

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Abstract

The combining ability for nine attributes was studied using Line x Tester mating design involving 5 lines and 7 testers in castor (*Ricinus communis* L.). The estimated components of *gca* and *sca* variances showed the preponderance of nonadditive gene action for all the characters. The female JP-81 was good general combiner for seed yield per plant and some other important yield attributing characters. Among males DCS-47, JI-127 and JI-251 were found good general combiners for yield per plant and other related attributes. The highest *sca* effect was exhibited by the cross combination JP-81 x DCS-47 for seed yield per plant. The cross combination JP-82 x DCS-47 showed highest *sca* effect for number of capsules on primary raceme. The highest *sca* effect for number of effective spikes per plant was recorded by the cross JP-83 x DCS-47. The parents with high *gca* and crosses with high *sca* effects should be exploited for further breeding programmes. The crosses with high *sca* effects for yield per plant and other important yield attributing characters should be exploited for heterosis breeding.

Key words : Combining ability, *gca*, *sca*, castor.

Introduction

Constant efforts to improve yield through hybridisation and selection of the parents for hybridisation programme are important in all crop improvement programmes. Therefore, in any sound-breeding programme, the proper choice of parents based on their combining ability is a pre-requisite. Such studies intended to determine the combining ability, not only provide necessary information regarding the choice of parents but also simultaneously illustrate the nature and magnitude of gene action involved. Accordingly, the present investigation was undertaken to have an idea of the nature of combining ability for yield and other yield attributing characters through Line x Tester analysis of some newly developed male and female lines of castor (*Ricinus communis* L.).

Materials and methods

Five pistillate lines (JP-78, JP-81, JP-82, JP-83 and SKP-4) and seven pollen parents were selected on the basis of desirable agronomic characters and wide genetic base (Table 2). The resulting 35 hybrids along with 12 parents were laid out in a RBD with two replications at Oilseeds Research Station, Gujarat Agricultural University, Junagadh during 1998-99. Each plot consisted of 12 plants having an inter and intra row spacing of 90 cm x 60 cm. Observations were recorded on five randomly selected plants for nine characters *viz.*, days to 50% maturity of primary spike, 100 seed weight (g), no. of capsules on primary raceme, no. of nodes up to main spike, total length of main spike (cm), effective length of main spike (cm), height up to primary raceme (cm), no. of effective spikes per plant and seed yield per plant (g). The data were analysed according to the method suggested by Kempthorne (1957).

Results and discussion

The analysis of variance showed significant differences among the genotypes for all the characters except for effective length of main spike indicating the presence of considerable amount of genetic variability (Table 1). The significant value of parents Vs crosses indicated the presence of heterosis in the crosses. Among lines, significant differences were observed for 100-seed weight, number of nodes upto main spike, total length of main spike and height up to primary raceme. Significant variances for males were recorded for 100-seed weight, number of capsules on primary raceme, number of nodes upto main spike, total length of main spike and height up to *primary raceme. The mean squares due to Lines x* Testers were highly significant for days to 50% maturity of primary spike, 100-seed weight, height up to primary raceme and seed yield per plant.

Estimates of variances revealed that variances due to gca (lines) were higher than those due to *gca* (tester) for days to 50% maturity of primary spike, height upto primary raceme and seed yield per plant indicating greater

Among the female parents, JP-81 was good general combiner for seed yield per plant, number of capsules on primary raceme, total length of main spike and effective length of main spike (Table 2). Among the pollen parents, the tester DCS-47 was the best general combiner for seed yield per plant. It was also a good general combiner for number of capsules on primary raceme, total length of main spike, effective length of main spike, and number of effective spikes per plant. Among the pollinators, JI-127 and JI-251 were good general combiners for seed yield per plant. The tester JI-251 was found good general combiner for 100-seed weight, number of capsules on primary raceme, total length of main spike and effective length of main spike.

The estimated *sca* effects (Table 3) revealed that the best combinations were JP-81 x DCS-47 (158.53), JP-82 x JI-251 (82.76), JP-81 x JI-127 (63.56) and JP-83 x JI-122 (49.53) for seed yield per plant; JP-81 x DCS-47 (-5.76), JP 82 x JI265 (-5.91) and JP-78 x JI-122 (-4.69) for days to 50% maturity of primary spike; SKP-4 x JI-226 (4.30) and JP-78 x JI-251 (3.29) for 100-seed weight; JP-82 x DCS-47 (26.63) for number of capsules on primary raceme. The highest negative *sca* effects for number of nodes upto main spike was exhibited by JP-83 x DCS-47 (-1.75). Total length of main spike (11.86) and effective length of main spike (12.70) was exhibited by the cross JP-82 x DCS-47. The cross combination JP-78 x DCS-47 (-13.20) exhibited the highest negative *sca* effect for height up to primary raceme. For number of effective spikes per plant the hybrid JP-83 x DCS-47 (2.00) was the best specific combiner. The crosses showing significant *sca* effects have fair chances for producing transgressive segregants.

Specific combining ability effects revealed that the cross JP-81 x DCS-47 showing high *sca* effects for yield per plant involved both good combining parents. Looking to the magnitude of variance due to *sca*, it is obvious that all the characters under investigation were governed by non-additive type of gene action. Under such circumstances the parents with high *gca* effects and cross combination with the highest *sca* effect for yield per plant should be considered for the commercial exploitation of heterosis in castor.

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Table 3 Specific combining ability effects in castor

Source	Days to 50% maturity of primary spike	100 seed *weight (g)*	No. of capsules on *primary* raceme	No. of nodes *upto main* spike	Total length of main spike (cm)	Effective length of *main spike* (cm)	Height up to primary raceme (cm)	No. of effective spikes/ plant	Seed yield/ plant (g)
JP-78 x JI-122	-4.69**	-1.22	14.73	0.62	2.40	2.04	7.20	0.21	35.69
JP-78 x JI-127	-3.19	-0.05	-1.17	-0.74	-0.60	-0.56	-3.40	-0.99	-30.85
JP-78 x JI-221	0.91	-0.74	0.13	0.18	0.00	-0.06	-2.60	-0.19	-7.90
JP-78 x JI-226	1.11	-1.23	-3.77	-1.06	-1.30	-1.26	0.80	-0.19	4.01
JP=78 x JI-251	0.51	3.29**	-0.47	-0.58	3.20	4.34	-3.20	0.61	41.26
JP=78 x JI-265	5.51**	-0.40	5.93	1.28	3.30	3.64	14.40*	0.81	10.70
JP-78 x DCS-47	-0.18	0.35	-15.37	0.28	-7.00	-8.16	-13.20*	-0.29	-52.93
JP-81 x JI-122	1.24	-1.19	-3.13	0.55	1.61	1.40	-11.80	0.86	-38.05
JP-81 x JI-127	2.24	0.32	-8.03	-1.41	-4.39	-4.70	-10.90	0.66	63.56*
JP-81 x JI-221	1.84	-0.05	-1.23	-0.99	-4.79	-4.70	-0.60	-1.04	-81.09**
JP-81 x JI-226	0.04	-2.43	6.37	-0.53	1.41	1.10	-2.20	0.46	25.07
JP=81 x JI-251	0.94	2.55	11.17	2.35*	1.91	2.20	21.80**	-0.74	-113.73**
JP=81 x JI-265	-0.56	0.27	-7.43	0.51	0.51	1.00	-8.10	-0.04	-14.29
JP-81 x DCS-47	-5.76**	0.53	2.27	-0.49	3.71	3.70	11.80	-0.14	158.53**
JP-82 x JI-122	3.39	-0.58	-9.77	-0.71	-4.74	-4.10	-0.16	-0.57	-34.66
JP-81 x JI-127	0.89	0.41	-6.67	0.73	-0.24	0.30	-0.76	1.23	-34.70
JP-82 x JI-221	-1.51	-1.33	0.63	0.15	-2.14	-2.20	2.54	0.53	25.35
JP-82 x JI-226	-0.31	1.17	-5.77	-0.99	-4.44	-3.90	-5.56	-0.47	2.96
JP=82 x JI-251	0.59	-0.39	-6.97	-1.61	-1.44	-2.30	-10.06	0.33	82.76**
JP=82 x JI-265	-5.91**	0.32	1.93	0.05	1.16	-0.50	1.04	0.03	17.10
JP-82 x DCS-47	2.89	0.40	26.63**	2.35*	11.86*	12.70*	12.94*	-1.07	-58.83**
JP-83 x JI-122	2.03	2.32	7.23	0.49	5.83	5.90	6.77	0.00	49.53
JP-83 x JI-127	-2.47	-0.09	12.33	0.93	5.83	5.80	12.67*	-0.70	57.64*
JP-83 x JI-221	1.63	1.97	0.63	0.65	4.93	4.80	1.47	-0.40	25.49
JP-83 x JI-226	-1.67	-1.81	-9.77	0.61	-6.87	-6.90	-5.63	-0.40	-52.60
JP=83 x JI-251	-2.77	-5.48**	-2.47	-0.11	-0.87	-1.80	-1.63	-0.10	-39.10
JP=83 x JI-265	-2.77	1.49	9.43	-0.85	0.23	1.00	-1.53	-0.40	.25.71
JP-83 x DCS-47	6.03**	1.60	-17.37*	-1.75	-9.07	-8.80	-12.13	2.00*	-15.24
SKP-4 x JI-122	-1.97	0.67	-9.06	-0.96	-5.10	-5.24	-2.01	-0.50	-12.51
SKP-4 x JI-127	2.53	-0.60	3.54	0.48	-0.60	-0.84	2.39	-0.20	-55.65*
SKP-4 x JI-221	-2.87	0.15	-0.16	-0.002	2.00	2.16	-0.81	1.10	38.14
SKP-4 x JI-226	0.83	4.30**	12.94	1.96	11.20	10.96*	12.59*	0.60	20.55
SKP-4 x JI-251	0.73	0.02	-1.26	-0.06	-2.80	-2.44	-6.91	-0.10	28.80
SKP-4 x JI-265	3.73*	-1.67	-9.86	-1.00	-5.20	-5.14	-5.81	-0.40	12.19
SKP-4 x DCS-47	-2.97	-2.88	3.84	-0.40	0.50	0.56	0.59	-0.50	-31.53
SE (Sij)	1.82	1.60	8.52	1.13	4.98	5.00	6.30	0.80	28.38
(Sij-Sjk)	2.57	2.27	12.04	1.60	7.05	7.08	8.91	1.13	40.13
CD (0.05)	3.57	3.14	16.70	2.21	9.76	9.80	12.35	1.57	55.62
CD (0.01)	4.69	4.12	21.95	2.91	12.83	12.88	16.23	2.06	73.10

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

Table 1 The gca effects, predictability factor and correlation coefficient (r) among parental mean (Xi) array mean (X.i) and *gca* effect (gi) for 14 characters in an 1x11 diallel set of crosses (F_1) in sesame

Parent	DF@	DM	PH	HFC	BP	CMS	CP	CL	CB	SC	SW	OC	SY	HI
X 174-9	-0.25	-2.94**	12.67**	5.33**	-0.25**	-0.89**	-7.12**	-0.42**	0.09	11.52**	-0.11**	0.92**	-2.02	-0.06**
RT 4	-1.33**	2.11**	-4.23**	-2.19**	-0.79**	-2.04**	-12.97**	1.00**	0.47**	2.66**	0.24**	0.78**	-2.28	-0.01
UT 43	-0.07	2.89**	-5.37**	-0.98	0.46**	-4.77**	-3.67**	1.25**	0.47**	1.11**	0.41**	1.16**	0.37	0.00
RAUSS - 1	1-0.87**	-2.17**	0.29	7.80**	-0.06	2.69**	1.47*	-0.27	-0.13*	1.35**	-0.14**	1.43**	-0.33	0.02**
TC 25	-1.33**	-10.13**	-6.66**	-2.88**	-0.08	-2.81**	-2.87**	-0.02	-0.05	0.84*	0.14**	1.32**	-0.52	0.03**
EC 115785	0.11	5.21**	3.42**	-5.93**	-0.43**	0.89*	-2.99**	1.45**	-0.02	2.01**	-0.20**	-2.94**	-0.91**	-0.03**
Kanak	-0.41*	-2.43**	-3.81**	-3.98**	0.33**	-0.77	7.54**	-0.27	0.08	-1.40**	0.09**	-1.84**	1.44**	0.05**
Zodade	3.08**	3.87**	7.62**	6.78**	0.01	2.23**	4.63**	0.24	-0.25**	-0.95**	-0.09**	2.13**	0.81**	0.00
Kayamkulam 1	0.57**	-3.72**	2.44**	1.61**	0.38**	0.52	5.74**	-1.04**	-0.29**	6.60**	-0.15**	-0.31**	0.99**	0.01
B 67	0.34*	4.23**	-1.32	-1.94**	-0.24**	4.44**	5.34**	-0.67**	-0.42**	-4.67**	-0.28**	-3.48**	0.77**	-0.02**
TNAU 11	0.16	2.95**	1.78*	-3.93**	0.68**	0.50	9.90**	-0.28*	0.05	-5.87**	0.08**	0.83**	1.81**	0.01
SE (gi)	0.16	0.28	0.80	0.55	0.05	0.43	0.73	0.14	0.05	0.35	0.01	0.03	0.29	0.01
SE (gi-gj)	0.24	0.42	1.18	0.81	0.08	0.64	1.08	0.21	0.08	0.52	0.01	0.05	0.44	0.01
Predictability factor	0.99	0.60	0.71	0.61	0.58	0.45	0.58	0.51	0.48	0.48	0.73	0.75	0.46	0.58
r (Xi, X.i)	0.98**	0.89**	0.95**	0.83**	0.86**	0.48	0.77**	0.59	0.57	0.79**	0.91**	0.96**	0.65*	0.80**
r (xi, gi)	0.99**	0.89**	0.96**	0.52	0.88**	0.66**	0.86**	0.89**	0.71*	0.89**	0.88**	0.97**	0.74**	0.82**
r (X.j, gi)	1.00**	0.99**	1.00**	0.32	1.00**	0.97**	0.99**	0.69*	0.98**	0.98**	0.99**	1.00**	0.99**	0.99**

*,** Significant at 5 and 1 per cent levels, respectively; @ Abbreviations for the characters as in table 2

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Combining ability and heterosis for yield and yield components in sesame (*Sesamum indicum* L.)

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Abstract

Fifty five F_1s from a half-diallel cross set were evaluated along with 11 parents to estimate combining ability and heterosis for 14 characters. Additive genetic variance was preponderant for days to flowering, plant height, 1000-seed weight and oil content. However, for the remaining characters both additive and non-additive gene actions were found to be equally important. TNAU 11, Kanak and Kayamkulam 1 were the best general combiners for seed yield. Heterotic hybrids were more frequently observed in crosses involving high x low *gca* parents. The correlations of *gca* effects with parental *per se* performance and sca effects with heterosis were highly positive and significant.

Key words : Combining ability, heterosis, sesame.

Introduction

Breeding methods for crop improvement depend upon the nature and magnitude of genetic variance controlling inheritance of the quantitative characters. Combining ability is frequently utilised to understand the nature of genetic variation which in turn helps in selection of desirable parents for hybridization programme or identification of superior crosses for commercial exploitation of heterosis. The present investigation has been undertaken to estimate combining ability of the parents and to study relationship between heterosis and combining ability.

Materials and methods

A half-diallel set was made by using 11 sesame parents selected from the germplasm collection maintained in the All India Coordinated Research Project on sesame at O.U.A.T., Bhubaneswar (Table 1). The parents along with $55F_1$s were grown in randomized block design with three replications at the Central Research Station, O.U.A.T., Bhubaneswar during both summer and *kharif* seasons. Observations were recorded on 10 randomly chosen competitive plants for 14 quantitative characters and mean values pooled over two seasons were used for statistical analysis (Table 2). Combining ability was estimated using mean value following Model I, Method 2 of Griffing (1956). Heterosis over mid-parent (Relative Heterosis) was worked out as per the standard procedure.

Table 2 The sca effects of F_1 hybrids for 14 characters showing range, number of hybrids with significant sca

Character	Range of *sca*	No. of hybrids with significant *sca*
Days to flowering (DF)	-1.47 to 2.04	50
Days to maturity (DM)	-15.83 to 6.38	51
Plant height(PH)	-11.57 to 14.66	47
Height upto first capsule (HFC)	-12.81 to 10.80	52
Branches/plant (BP)	-0.62 to 1.23	53
Capsules on main stem (CMS)	-7.24 to 8.38	49
Capsules/plant (CP)	-12.77 to 13.52	49
Capsule length (CL)	-2.26 to 5.53	50
Capsule breadth (CB)	-1.19 to 0.84	51
Seeds/Capsule (SC)	-9.68 to 9.74	48
1000-seed weight (SW)	-0.38 to 0.39	55
Oil content (OC)	-2.65 to 2.41	54
Seed yield/plant (SY)	-4.06 to 5.66	51
Harvest index (HI)	-0.079 to 0.124	55

Table 4 Heterosis and sca effects in the top ten hybrids for seed yield

Top yielding hybrids	Seed yield/plant		Capsules/plant		Branches/plant		Seeds/capsule	
	Heterosis	*sca*	Heterosis	*sca*	Heterosis	*sca*	Heterosis	*sca*
P3 x P9	68.1**	3.3**	31.0**	6.1**	40.7**	0.5**	9.6**	0.2
P3 x P11	49.8**	2.8**	48.3**	9.4**	22.2**	0.0	11.9**	3.4**
P4 x P10	50.5**	2.7**	25.9**	7.8**	30.3**	-0.2**	18.1**	7.8**
P7 x P8	31.2*	2.0**	8.8	4.3**	25.4**	0.6**	0.4	-1.6**
P7 x P9	34.9**	2.1**	15.2**	0.6	28.8**	0.1**	2.7	-1.1**
P8 x P9	45.1**	2.7**	14.8**	6.5**	17.6**	0.3**	4.0	1.4**
P8 x P10	83.5**	5.7**	36.3**	13.5**	18.6*	0.4**	1.7	-2.0**
P9 x P10	80.5**	1.5**	42.3**	6.7*	16.2	0.2**	1.7	-1.4**
P9 x P11	47.5**	1.1**	30.9**	2.3**	12.5	-0.4**	-5.3*	-5.1**
P10 x P11	70.4**	2.3**	65.1**	12.4**	35.1*	0.3**	3.5	0.9**

*,** Significant at 5 and 1 per cent levels respectively

x B67 and Zodade x TNAU 11 exhibiting high heterosis for seed yield offer scope for commercial exploitation through heterosis breeding with indentification of male sterile line, since presence of considerable amount of natural cross pollination is reported in sesame. Thus, breeding for pure lines and hybrids may possibly be integrated into one programme as heterotic hybrids are reported to produce superior homozygous lines through conventional breeding methods.

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Results and discussion

The analysis of variance revealed significant differences among 66 entries (11 parents and 55 F_1s) for all the 14 characters. The analysis of variance for combining ability showed that variances due to *gca* and *sca* were highly significant for all the traits. High predictability factor (>0.70) for the four characters, such as days to flowering, plant height, 1000-seed weight and oil content indicated that additive gene effects were predominant for these characters (Table 1). For the remaining 10 characters the predictability factor indicated more or less equal importance of both additive and non-additive gene action.

The estimates of *gca* effects revealed that TNAU 11, Kanak, Kayamkulam 1, Zodade and B 67 were good general combiners for seed yield and they were also found to be good general combiners for capsules/plant and other yield components, e.g., Kanak exhibited high *gca* for nine characters, while TNAU 11, Zodade and TC 25 showed high *gca* for six characters. Zodade, RAUSS 1, TC 25 and UT 43 were found to be good general combiners for oil content (Table 1).

High significant correlation of parental means with array mean and *gca* effects suggested that *per se* performance may be an effective tool for selecting parents for hybridization programme (Table 1). Similar observations were also reported in sesame by Sharma and Chauhan, 1985. Thus, the choice of parents on the basis of *per se* performance for hybridization may be effective, when the character is unidirectionally controlled by a set of alleles and additive effects are more important. However, in cases where non-allelic interactions are more important, the combining ability estimate must be considered for parental choice.

The *sca* effects were highly significant in most of the crosses for all the characters and the range of *sca* effects for most of the characters appeared to be very large (Table 2). When seed yield and its important components, such as branches/plant, capsules/plant, seeds/capsule and 1000-seed weight were considered, UT 43, Kayamkulam 1 and B 67 were found to be involved more frequently in hybrids having high *sca* effects. Kayamkulam 1, Zodade, B 67, RAUSS 1 and UT 43 were found to be involved more frequently in hybrids showing high *sca* effects when all the 14 characters were considered.

The crosses involving high x low *gca* parents produced more heterotic hybrids for seed yield and its component traits than high x high or low x low *gca* parents (Table 3). The importance of parental diversity for *gca* in realising heterosis as observed from the present study and also reported earlier in sesame (Goyal and Kumar, 1988; Mishra and Yadav, 1996) could be possible due to compatible and complementary action of divergent genes present in the parents to provide harmonious physiological functioning in hybrids. Heterotic hybrids found in respect of high x high *gca* parental combinations in certain cases due to accumulation of additive genes in the hybrids from both the parents. Hence it may be possible to select high yielding recombinants from the segregating generations following simple pedigree method.

Table 3 Frequency of parental combination for gca in 55 sesame hybrids for seed yield and other related characters

Character	No. of significant heterotic hybrids for *gca* combinations			
	High x High	High x Low	Low x Low	Total
Seed yield/plant	8	11	4	23
Capsules/plant	6	14	10	30
Branches/plant	7	16	10	33
Seeds/capsule	4	19	4	27
1000-seed weight	2	9	3	14
Total	27	69	31	127

Heterosis and *sca* level of parents in respect of the 10 top yielding hybrids for seed yield and three yield components showed that seed yield for all the ten hybrids had significant positive heterosis as well as significant *sca* effects. The number of hybrids exhibiting significant heterosis to those with significant *sca* effects was 9 to 9 for capsules/plant, 8 to 7 in branches/plant and 3 to 4 in seeds/capsule. The overall correlation between heterosis and *sca* effects in the 55 crosses was positive and highly significant for seed yield (r=0.815**), capsules/plant (r = 0.809**) and seeds/capsule (r = 0.905**). Highly significant positive correlation coefficients between heterosis and *sca* in the present study supported the view that heterosis and *sca*, both being influenced by non-additive gene action, are expected to be associated.

In the present study, both additive and non-additive gene actions were found important in the inheritance of the characters studied. There is also possibility of upward bias in the estimation of additive gene action due to epistasis. It is, therefore, necessary to follow modified breeding methods, such as bi-parental cross or triple test cross design or recurrent selection method for exploitation of non-additive gene action in order to recover transgressive segregants by breaking linkages, releasing concealed variability and changing linkage equilibrium. In the present investigation, potential crosses like RT 4 x Kanak, RT 4 x Zodade, TC 25 x Kanak, TC 25 x B 67, EC 115785 x TNAU 11, Zodade x Kayamkulam 1, Zodade

Table 1. Passport information of the accessions

No.	Species Name	ICG No@.	Origin	Latitude	Longitude
1.	*A.batizocoi* Krap.et Greg.	8124	Bolivia	20°50'S	63°10'W
2.	*A.batizocoi* Krap.et Greg.	8209	Bolivia	20°17'S	63°28'W
3.	*A.batizocoi* Krap.et Greg.	8210	Bolivia	19°40'S	63°41'W
4.	*A.batizocoi* Krap.et Greg.	8958	Bolivia	19°44'S	63°36'W
5.	*A.cardenasii* Krap. et Greg. *nom.nud.*	8216	Bolivia	18°20'S	59°46'W
6.	*A.cardenasii* Krap. et Greg. *nom.nud.*	8132	Argentina	27°33'S	58°46'W
7.	*A.cardenasii* Krap. et Greg. *nom.nud.*	8918	Argentina	NA	NA
8.	*A.diogoi* Hoehne	4983	Paraguay	NA	NA
9.	*A.duranensis* Krap. et Greg. *nom.nud.*	8123	Argentina	22°19'S	63°43'W
10.	*A.duranensis* Krap. et Greg. *nom.nud.*	8139	Argentina	24°47'S	65°32'W
11.	*A.duranensis* Krap. et Greg. *nom.nud.*	8196	Argentina	24°16'S	65°12'W
12.	*A.duranensis* Krap. et Greg. *nom.nud.*	8200	Argentina	23°03'S	63°56'W
13.	*A.duranensis* Krap. et Greg. *nom.nud.*	8201	Bolivia	21°48'S	63°33'W
14.	*A.duranensis* Krap. et Greg. *nom.nud.*	8205	Bolivia	21°18'S	63°27'W
15.	*A.duranensis* Krap. et Greg. *nom.nud.*	8207	Bolivia	20°37'S	63°13'W
16.	*A.duranensis* Krap. et Greg. *nom.nud.*	8208	Bolivia	20°45'S	63°08'W
17.	*A.duranensis* Krap. et Greg. *nom.nud.*	8956	Argentina	23°04'S	63°53'W
18.	*A.duranensis* Krap. et Greg. *nom.nud.*	8957	Bolivia	21°26'S	63°27'W
19.	*A.helodes* Mart.ex Krap.et Greg.	8955	Brazil	16°03'S	57°13'W
20.	*A.hoehnei nom.nud.*	8190	Brazil	18°08'S	57°30'W
21.	*A.hypogaea* L. ssp. *hypogaea* var.*hypogaea* , bunch type	5813	Argentina	NA	NA
22.	*A.hypogaea* L. ssp. *hypogaea var.hypogaea* , runner type	5770	Argentina	NA	NA
23.	*A.hypogaea ssp.fastigiata var.vulgaris* Harz	287	Argentina	NA	NA
24.	*A.hypogaea* ssp. *fastigiata* Waldron var. *fastigiata*	3704	Argentina	NA	NA
25.	*A.kempf-mercadoi* Krap. et Greg et Simpson *nom.nud.*	8164	Bolivia	NA	NA
26.	*A.kempf-mercadoi* Krap. et Greg et Simpson *nom.nud.*	8959	Bolivia	17°19'S	63°18'W
27.	*A.khulmanii* Krap.et Greg.*nom.nud.*	8954	Brazil	16°05'S	57°15'W
28.	*A.monticola* Krap.et Rig	8197	Argentina	24°07'S	65°23'W
29.	*A.monticola* Krap.et Rig	8198	Argentina	24°04'S	65°24'W
30.	*A.monticola* Krap.et Rig	8135	Argentina	24°07'S	65°24'W
31.	*A.stenosperma* Krap.et Greg. *nom.nud.*	8125	Brazil	25°24'S	48°44'W
32.	*A.stenosperma* Krap.et Greg. *nom.nud.*	8126	Brazil	25°31'S	48°31'W
33.	*A.stenosperma* Krap.et Greg. *nom.nud.*	8137	Brazil	25°24'S	48°44'W
34.	*A.stenosperma* Krap.et Greg. *nom.nud.*	8906	Brazil	25°31'S	48°31'W
35.	*A.valida nom.nud.*	11548	Brazil	19°11'S	57°29'W

@ = ICRISAT groundnut accessions number

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Taxonomical relationships based on leaf and stem anatomy among *Arachis* species of the section *Arachis*

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Abstract

Anatomical characters have been used in systematics to delimit taxa at various levels. In the genus *Arachis* the anatomical studies were confined to structure and development and the characters were correlated with tolerance/resistance to various biotic and abiotic stresses. This study was aimed to use anatomical traits in finding relationship among the *Arachis* species of the section *Arachis*. Anatomy of both leaflet and stem were studied and cluster analysis was done for establishing taxonomical relationship. The cytologically related species, *A. hypogaea* and *A. monticola*, are found to be closely related by anatomical features and found grouped in the same cluster. High intraspecific variation was observed for *A. batizocoi* and *A. duranensis* for majority of the traits. However, the close relationship between the amhiploid species showed that these characters might be useful in studying taxonomical relationships in collation with morphological and embryological characters.

Key words : Accessions, cluster analysis, trichomes, stomata, parenchyma, taxonomy.

Introduction

Anatomical characters were used for the first time to delimit taxa at various levels within the family *Bignoniaceae* as early as in 1864 (Sivarajan, 1984). Hickey (1973) proposed terminology to describe various architectural features of dicotyledonous leaf. Since then, anatomical traits have been frequently used to describe and delimit various taxa. The genus *Arachis* is economically important, as it contains peanut (*A. hypogaea*), which is a source of edible oil and is also widely used for table purposes. The genus is divided into nine sections and the section *Arachis* comprises species belonging to primary and secondary gene pool of peanut, which are potential donors of resistance to abiotic and biotic stresses (Stalker and Simpson, 1995). In the genus *Arachis* the preliminary studies on anatomy of root, stem and leaves were done with an emphasis on the structure and development (Yarbrough, 1957; D'Cruz and Upadhyay, 1961; Kothari and Shah 1975). Correlation of anatomical traits like number of tannin sacs, trichome density and other structural variation with various biotic stresses (Suryakumari *et al.* 1984; Dwivedi *et al.* 1986; Mayee and Suryawanshi 1995) were also reported in *Arachis*. The present studies focus on comparative anatomy of leaflet and stem of *Arachis* species of section *Arachis* so as to use these traits for studying taxonomical relationships.

Materials and methods

Thirty-five accessions belonging to 13 spices of *Arachis* of the section *Arachis* including four accessions of *A.hypogea* belonging to four habit types were procured from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and grown in unreplicated plots (2.8x3.5 m^2) during 1996-97 at NRCG, Junagadh, Gujarat, India. The passport information of the accessions studied have been listed in table 1.

All the leaf anatomical characters were recorded on the 3rd leaf from the apex on the main stem of 110 days old plants. Number of trichomes/mm of leaf margin was counted from five microscope fields in three replications and for trichome length an average of ten trichomes at random were measured. Stomatal length and width (when the guard cells were fully turgid) were measured from the epidermal peeling of fresh leaf. To compute the average, 20 stomata each from both surfaces of the leaf were measured from three plants each. Epidermal impression on thin layer of fevicol (synthetic glue) film from both abaxial and adaxial surface was used for studying stomatal frequency and for counting number of epidermal

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Table 2 Distribution of accessions of groundnut for trichome length and density at leaf margin

Trichome length range (mm)		Accessions
0.0-0.5	ICG	8955.
0.5-1.0	ICGs	8196, 8126, 8132, 8164, 8207, 8906, 8137, 4983.
1.0-1.5	ICGs	287, 8215, 8197, 8197, 8210, 8957, 8959, 8956, 8190, 8123, 8200, 11548, 8918, 8205, 8139, 8954.
1.5-2.0	ICGs	8958, 8216, 8208, 8198, 8124, 3704, 5813, 8135, 5770, 8201
Trichome density range (no mm^{-1})		
0-10	ICG	8955
10-20	ICGs	8190, 8164, 8123, 8207
20-30	ICGs	287, 8126, 8197, 8957, 8198, 8124, 8200, 5770, 8954, 8205, 8201, 8139
30-40	ICGs	8125, 8196, 8209, 8959, 8956, 8216, 8208, 5813, 8135, 8906, 11548
40-50	ICGs	8210, 8958, 3704, 8137, 4983
50-60	ICG	8132, ICG 8918

cells. Five microscope fields with an area of $0.3315mm^2$ in three replications were observed on both surfaces and calculated the number of cell mm^{-2}. Stomatal index was calculated by using formula:

SI = [no. of stomata/(number of stomata + number of epidermal cells)] x 100.

For studying the internal striation of various tissues of the leaflet, the midrib region leaving one cm from the base of the leaflet was sampled and fixed in FAA. Paraffin embedding method (Johansen, 1940) was used to prepare permanent serial transverse section (TS) with safranine/fast green double staining. Observations were taken randomly from five slides each of three replications. Thickness of lamina, midrib, epidermis, palisade layer, spongy tissue layer and water storage layer were measured using ocular micrometer. Number of palisade cells $0.35mm^{-1}$ and breadth of the individual palisade cell were recorded and index was calculated as: [number of palisade cells] x [average breadth of palisade cell] to express the compactness in arrangement of palisade tissue. The numbers of tannin sacs at 1.1 mm length on TS of leaflet were also recorded. Tissue ratio was calculated with the thickness of the specific layer to the total thickness of the lamina.

For anatomical studies of stem, the first inter-node above the cotyledonary node was sampled from 110 days old plants. Permanent slides of transverse section were prepared by hand sectioning followed by dehydrating in alcohol/xylene series. Double staining with safranine and fast green was used to distinguish striation of tissues. Observations were taken at random from five slides in three replications.

Cluster analysis was done based on unweighted pair group method using arithmetic averages (Sneath and Sokal, 1973). Squared euclidian distance was used as measure of distance and the actual values were standardized so as to get mean zero and variance 1.

Results and discussion

Epidermal structures on lamina

Trichomes: Trichomes were uniseriate in all accessions studied and the average trichome length on leaf margin ranged between 0.2 mm in *A. helodes* (ICG 8955) and 2.0 mm in *A. duranensis* (ICG 8208). Variation within the *A. duranensis* species, was 1 mm to 2 mm. *A. batizocoi*, *A. cardenasii*, *A. monticola*, ICG 8201 (*A. duranensis*) and *A. hypogaea* showed similarity in trichome length. The frequency distribution of accessions for trichome length and density is given in table 2. The average number of trichomes/mm ranged between 9.1 in *A. helodes* and 56.8 in ICG 8132 (*A. correntina*). Among *A. hypogaea* the density was highest in ssp. *fastigiata* (47.2) followed by ssp. *hypogaea* (35.5 and 26.8) and ssp. *vulgaris* (26.0). The *fastigiata* accession showed more resemblance to the

Table 3 Mean anatomical traits of leaflet of groundnut accessions

ICG	sll	swl	mel	sil	le	lp	msp	wst	mr	lt	tc
8124	21.1±0.2	18.1±0.0	261.8±1.1	27.0±1.6	14.0±1.2	122.9±2.4	49.0±1.2	48.6±1.8	460.4±2.7	231.0±2.3	9.2±0.0
8209	21.1±0.4	18.2±0.2	476.9±4.7	18.8±0.3	13.2±0.7	61.4±0.7	28.8±0.7	29.2±1.2	350.0±0.0	157.1±1.4	7.5±0.3
8210	22.1±0.0	20.1±0.6	352.9±1.2	19.7±0.3	14.4±1.4	111.2±1.4	31.1±1.4	30.3±0.0	437.1±4.9	214.7±2.3	7.9±0.7
8958	21.4±0.0	18.4±0.0	346.8±0.6	18.5±0.6	12.8±0.0	105.4±0.7	32.3±1.4	30.7±0.7	362.4±3.6	220.9±1.4	6.7±0.1
8216	21.6±0.2	18.4±0.0	340.0±7.6	18.7±0.5	19.8±0.0	95.7±0.0	38.5±0.0	32.3±0.7	631.5±1.4	255.9±3.6	9.4±0.0
8132	20.9±0.2	17.6±0.2	402.5±2.4	21.7±0.5	12.4±0.7	85.6±0.7	39.7±1.2	31.1±0.7	477.5±5.9	211.5±1.4	8.5±0.1
8918	21.4±0.0	15.4±0.2	434.9±1.6	23.6±0.3	14.4±0.7	75.8±1.2	29.6±0.7	33.4±0.7	346.9±1.4	171.1±3.6	7.3±0.6
4983	19.0±0.0	16.0±0.0	374.8±5.9	20.7±0.7	16.3±1.2	86.3±1.2	37.3±1.2	33.8±0.0	592.6±2.4	221.7±2.3	6.1±0.4
8123	18.8±0.0	16.0±0.2	396.9±6.7	19.7±0.1	15.6±0.7	103.1±1.8	52.9±1.8	32.3±0.7	453.4±3.6	213.9±1.4	8.1±0.2
8139	18.5±0.0	16.7±0.0	391.9±0.4	20.4±0.6	16.7±0.7	66.1±1.8	37.3±1.2	34.6±1.4	529.6±0.0	143.1±1.4	9.8±0.0
8196	21.1±0.9	15.0±0.2	489.8±3.4	20.8±0.5	18.3±0.7	110.4±1.4	55.2±0.7	33.8±0.0	482.2±1.4	216.2±1.4	4.8±0.4
8200	20.8±0.2	18.1±0.0	393.7±5.8	20.0±0.8	11.7±0.0	59.5±1.2	27.2±0.7	31.1±0.7	382.6±4.0	168.3±1.4	7.9±0.2
8201	18.8±0.0	15.5±0.0	421.4±5.6	21.2±0.5	18.7±1.2	74.7±1.2	47.8±2.0	47.8±1.2	648.6±2.4	213.1±1.4	6.8±0.4
8205	18.7±0.2	15.6±0.6	437.5±0.4	23.5±0.4	20.2±0.7	66.5±1.2	38.1±0.7	37.3±1.2	472.9±2.7	171.1±1.4	6.4±0.2
8207	19.0±0.2	17.3±0.4	421.8±2.4	19.6±0.3	15.9±0.7	60.7±1.2	27.6±0.7	35.0±1.2	522.6±2.3	191.3±4.0	8.4±0.0
8208	19.9±0.0	16.2±0.0	312.5±7.3	25.1±1.0	20.6±0.7	49.4±0.77	24.5±0.0	40.8±0.0	521.1±2.7	158.7±0.0	6.3±0.5
8956	19.2±0.0	15.7±0.4	383.0±1.8	23.7±0.2	16.3±0.0	56.8±0.7	25.7±.1.2	25.3±0.7	289.3±0.0	159.4±1.4	8.1±0.2
8957	20.9±0.6	17.7±0.6	375.6±2.8	18.3±0.7	19.1±0.7	129.1±3.6	52.1±0.7	33.8±0.0	542.9±3.6	286.2±1.3	6.3±0.1
8955	18.8±0.0	15.4±0.2	431.9±3.8	17.8±0.4	15.9±0.7	48.6±1.4	25.7±0.0	24.5±1.2	287.0±2.3	120.5±1.4	6.2±0.2
8190	19.2±0.0	14.7±0.0	408.2±2.3	17.7±0.2	16.3±1.2	52.5±1.2	31.9±0.7	30.7±0.7	477.5±1.4	150.9±2.7	11.0±0.7
5813	28.9±0.4	18.4±0.0	290.1±1.1	21.2±0.1	23.7±1.4	91.0±1.2	34.2±2.9	49.4±0.7	790.2±8.2	225.5±2.7	3.0±0.2
5770	28.5±0.6	18.4±0.0	300.2±2.9	21.7±1.1	19.8±1.2	71.9±1.4	43.9±0.7	42.0±0.0	624.5±1.4	179.7±2.3	3.5±0.3
287	29.0±0.2	18.4±0.0	306.4±1.2	20.6±0.9	22.6±0.7	71.9±0.7	30.7±0.7	28.8±1.4	725.6±4.0	201.4±1.4	4.9±0.1
3704	28.4±0.6	18.9±0.9	294.6±1.5	20.5±0.8	20.2±0.7	70.8±1.8	35.0±2.3	35.4±1.4	576.3±2.3	181.2±1.4	5.3±0.2
8164	23.5±1.1	16.1±0.8	352.9±7.1	17.0±0.4	13.2±0.7	71.9±1.4	30.7±0.7	49.0±1.2	364.0±4.0	173.4±1.4	8.2±0.0
8959	21.2±0.4	18.3±0.2	435.3±3.4	19.7±0.1	11.7±0.0	105.8±0.7	33.8±1.2	35.4±0.7	340.6±0.0	240.3±0.0	5.8±0.2
8954	19.6±0.6	16.5±0.4	405.4±0.6	20.4±0.5	12.8±1.2	81.3±0.7	40.8±1.2	30.3±1.2	326.6±2.3	186.7±2.3	6.2±0.2
8197	28.6±0.2	18.8±0.0	248.5±2.6	20.0±2.1	18.7±0.0	63.0±0.0	28.4±0.7	30.3±0.0	448.8±3.6	168.8±1.4	4.6±0.0
8198	25.8±0.0	17.7±0.6	267.0±3.6	21.6±0.8	19.8±0.0	65.7±2.4	34.2±1.4	31.9±0.7	539.7±1.4	153.2±2.7	5.7±0.1
8135	26.2±0.0	18.8±0.4	258.0±2.4	20.5±0.6	16.7±0.7	73.1±1.4	36.9±0.7	43.6±1.4	654.1±2.7	175.8±1.4	3.6±0.2
8125	19.3±0.4	14.7±0.0	821.8±4.9	17.2±0.7	19.8±0.0	66.5±1.2	29.2±1.2	24.5±0.0	290.9±3.6	147.8±2.7	8.6±0.6
8126	21.0±0.4	14.7±0.0	475.5±0.9	22.1±0.3	13.6±0.7	64.6±0.7	35.8±0.7	30.3±0.0	325.1±4.9	181.2±1.4	5.9±0.1
8137	19.5±0.0	16.3±0.0	453.6±6.9	21.8±0.3	15.9±0.7	60.3±1.4	31.1±0.7	29.6±0.7	412.2±2.7	155.5±2.7	8.9±0.3
8906	18.8±0.0	16.2±0.0	618.5±2.4	20.9±0.3	10.5±1.2	70.8±0.7	38.5±1.2	28.8±1.4	295.5±5.9	168.0±2.3	9.1±0.3
11548	21.7±0.4	18.4±0.0	417.0±2.9	20.5±0.2	12.4±0.7	79.7±0.7	32.7±1.2	37.3±1.2	562.8±7.1	172.7±2.3	11.0±0.1

sll: Stomatal length adaxial surface (μm), swl: Stomatal width adaxial surface (μm), mel: No. of epidermal cell/mm^2 adaxial surface, sil: Stomatal index adaxial surface, le: Thickness of leaf epidermis (μm).
wst: Thickness of water storage tissue layer (μm), lp: Thickness of palisade tissue layer (μm), lt: Lamina thickness (μm), mr: Thickness of midrib (μm), msp: Thickness of spongy tissue layer (μm), tc: No. of tannin cells/mm

A. batizocoi, *A. diogoi*, and *A. stenosperma* in having long and high-density trichomes. *A. helodes* was almost glabrous having only a few short trichomes. It is apparent that during the course of evolution of the genus *Arachis*, the trichomes characteristics did not evolve much, as even the cultivated species exhibited longer trichomes and high trichome density. The trichomes on leaves are of significance in contributing to the resistance of peanut to jassids (Dwivedi *et al.* 1986).

Stomatal Apparatus

The stomatal type was mainly paracytic with one subsidiary cell distinctly smaller than the other in all the accessions studied (Fig A&B). Anisocytic type and abnormal type of sharing common subsidiary cell for two or more stomata were also observed at random. In sectional view the guard cells showed an outer ledge made of wall materials (Fig C). The average stomatal length was maximum in *A. hypogaea* with a range between 28.4 and 29.2 mm at abaxial surface and between 28.4 and 29.0 mm at adaxial surface among the four accessions (Table 3).

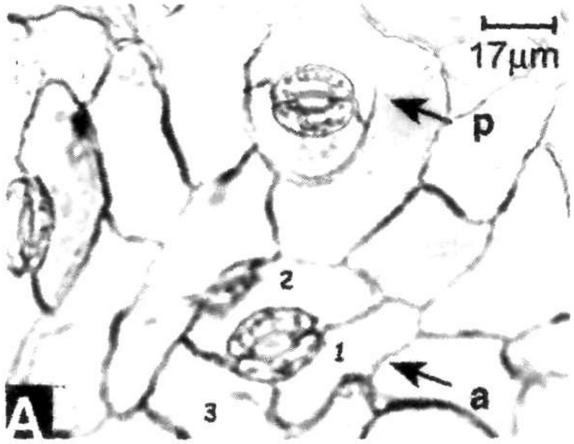

Fig A Epidermal peeling showing paracytic and anisocytic stomata (p=paracytic, a=anisocytic and 1,2,3 =subsidiary cells

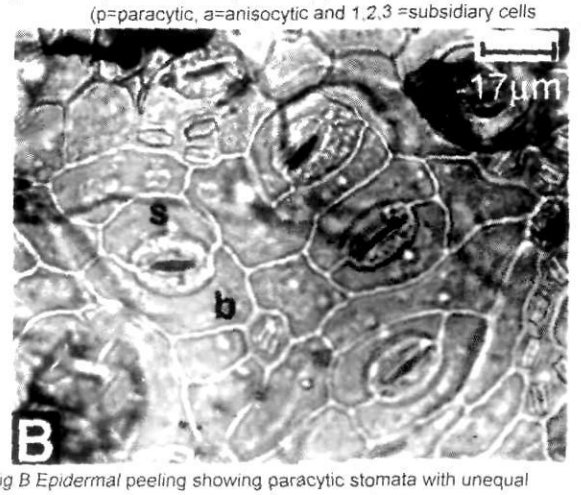

Fig B Epidermal peeling showing paracytic stomata with unequal subsidiary cells (s=smaller subsidiary cell, b=bigger subsidiary cell)

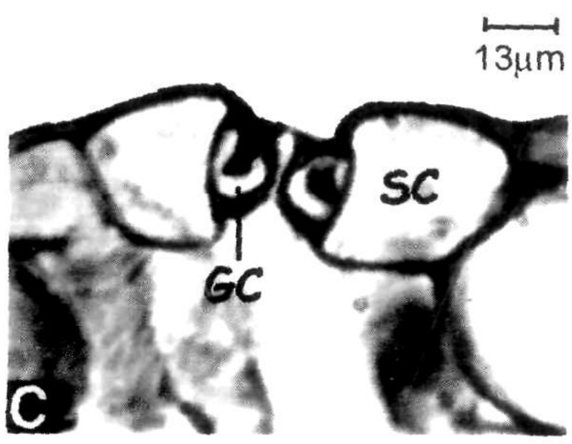

Fig C Transverse section of stomatum (sc=subsidiary cell, gc=guard cell)

The other tetraploid species *A. monticola* was also close to it with stomatal length of 25.8 to 28.7 μm at abaxial surface and 25.8 to 28.6 μm at adaxial surface. The diploid species exhibited smaller stomata with stomatal length ranging between 18.8 and 22.5 μm and between 18.7 and 23.5 μm at abaxial and abaxial surfaces, respectively. Suryakumari *et al.* (1989) reported the occurrence of longer stomata at abaxial surface in some wild and cultivated species. In the present studies, though the largest range was observed at abaxial surface, the F-test showed that there is no significant difference between the stomatal length of two surfaces. ICG 8210 (*A. batizocoi*) showed the maximum width of stomata 19.8 μm at abaxial surface and 20.1 μm at adaxial surface and the minimum width was 14.7 μm in *A.stenosperma*, *A.hoehnei*, and one accession of *A. duranensis*. Many accessions, ICGs 8957 and 8200 (*A. duranesis*), ICG 8959 (*A. kempff-mercadoi*), ICG 8216 (*A.cardenasii*), ICGs 8197 and 8135 (*A. monticola*), ICG 8958 (*A. batizocoi*) and ICG 11548 (*A. valida*) were close to *A. hypogaea* (18.2-18.5 μm) in stomatal width. There was no significant difference for stomatal width observed between abaxial and adaxial surface of the leaf.

Epidermal cell

The average number of epidermal cells ranged between 262.8 and 835.2 mm^{-2} at abaxial surface and between 248.5 and 821.8 mm^{-2} at adaxial surface for ICG 8197 (A. monticola) and ICG 8125 (*A. stenosperma*), respectively. The tetraploid members (*A. hypogaea* and *A. monticola*) showed lesser number of epidermal cells mm^{-2} (<310) indicating larger size of the epidermal cells compared to other species.

Stomatal frequency and index

In general, the accessions having larger leaflet size showed lower stomatal frequency. The range was between 66.4 and 192.6 mm^{-2} at abaxial surface and between 63.3 and 163.9 mm^{-2} at adaxial surface. The lowest frequency was shown by *A. monticola* accessions. The highest frequency was observed in ICG 8906 (*A. stenosperma*); 192.6 and 163.9 at abaxial and adaxial surface, respectively. Mayee and Suryawanshi (1995) reported the occurrence of fewer stomata on leaf in the resistant genotypes to late leaf spot disease. There was significant variation for stomatal index between abaxial and adaxial surface but the variation was not consistent to any one of the surfaces. Out of 35 accessions, 23 showed higher stomatal index at abaxial surface than adaxial. The stomatal index ranged from 11.8 to 26.7 at abaxial and 17.0 to 27.0 at adaxial surface. The stomatal index at adaxial surface with a few exceptions. *A. duranensis* showed highest stomatal index at abaxial surface and *A. batizocoi* at adaxial surface. Though the stomatal frequency was very low in the large foliaged accessions, the stomatal index was high as compared to other species, which is explained by the larger size of the epidermal cells in these accessions.

Transverse section (TS) of lamina

Epidermis

Epidermis is characterized by single layer of laterally elongated parenchymatous cells and frequently interrupted by the stoma (Fig D). There was no significant difference between the thickness of abaxial and adaxial epidermis. Here all the observations referred to is related to abaxial epidermis. The thickness of epidermis ranged between 10.5 and 23.7 μm, which was highest in *A. hypogaea* accessions. *A. cardenasii* and *A. duranensis* and *A. monticola* occupy the next strata (Table 3).

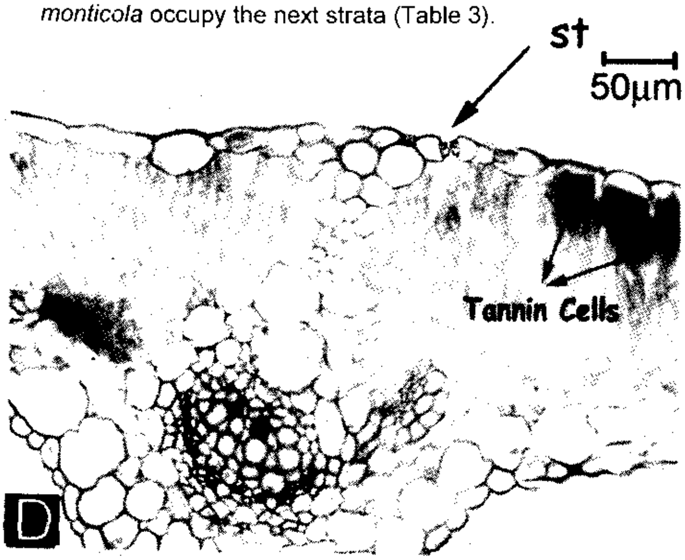

Fig D Transverse section of leaflet showing tannin cells (st=stomata)

Palisade parenchyma

Palisade parenchyma comprises three layered vertically elongated cells intercepted by the bundle sheath extension of veinlets. The width of the parenchyma cells and compactness in arrangement is varied amongst the accessions. The thickness of the parenchyma layer ranged between 49.4 (ICG 8208) and 129.1 μm (ICG 8957), both belongs to *A. duranensis*, indicating high intraspecific variation for this trait. The breadth of palisade cell ranged between 6.6 (ICG 4983) and 11.7 μm (ICGS 8126 and 8957). The number of parenchyma cells/128 mm length ranged between 7.5 (ICG 5770) and 13.4 μm in ICG 8198. The index (total number of palisade cell x palisade cell breadth) gives the compactness of the arrangement of palisade cells. The most compact arrangement was observed in ICG 8207 (*A. duranensis*) whereas *A. hoehnei* showed the most loosely arranged palisade cells. The accessions of *A. hypogaea* also showed loose arrangement with larger intercellular space. Godoy *et al.* (1985) reported that the genotypes resistant to pod rot exhibited most compact arrangement of palisade cells in cultivated peanut. Hence the species with higher index (*A. duranensis, A. correntina* and *A. kempff-mercadoi*) can probably be the donors for pod rot resistance. Palisade tissue ratio to the lamina thickness showed that ICG 8124 had the highest ratio (0.53) followed by ICG 8210 (*A. duranensis*). The lowest ratio was in ICG 8208. In general, the *A. hypogaea* had lower palisade tissue ratio.

Spongy parenchyma

The Intraspecific variation in *A. duranensis* is very high for the thickness of spongy parenchyma layer, which was between 24.5 and 55.2 μm. Spongy tissue ratio was highest in accessions of *A. duranensis* (ICGS 8196, 8123 and 8139) with 0.26. *A. hypogaea* ssp. *hypogaea* runner type accession also comes closer to the above ratio.

Water storage layer

The water storage cells are large parenchymatous cells modified by its function. Only one layered cells was observed and rarely of two layers near to the main vein (Fig E). The presence of this specified tissue is assigned to xerophytic nature of plants and the thickness of the layer may be assumed to be of better drought resistance (Reed, 1924). The thickness ranged from 24.5 to 49.4 μm. The highest value was shown by ICG 5813 (*A. hypogaea*) and the lowest by ICG 8125 (*A. stenosperma*). The water storage tissue ratio was highest in *A. kempff-mercadoi* accession followed by *A. duranesis*. The range was from 0.12 (ICG 8957) to 0.28 (ICG 8208). In *A. duranensis* accessions two extreme values of 0.12 and 0.26 were observed, though the thickness of water storage tissue layer was higher for *A. hypogaea, A. kempff-mercadoi* had the highest ratio because the former had thick lamina also.

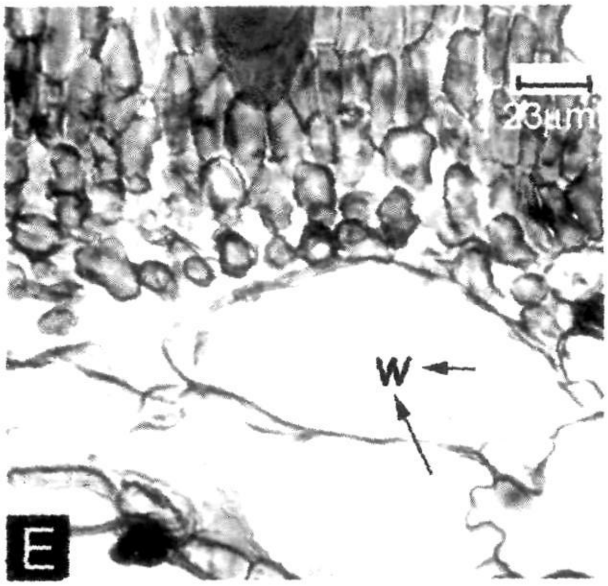

Fig E Transverse section of leaflet showing two layered water storage cells

Midrib and lamina

The accessions of *A. hypogaea* had thick midrib. Among wild species the midrib thickness is decreasing in the following order *A. cardenasii. A. monticola,* and ICG 8201 (*A. duranesis*). *A. helodes* and *A. stenosperma* had very thin midrib though the leaflet size of *A. stenosperma* is comparatively larger. Lamina thickness ranged between 143.3 µm (ICG 8139) and 286.2 (ICG 8957), both accessions belong to *A. duranensis. A. cardenasii* and *A. kempff-mercadoi* also had thick lamina compared to others.

Tannin cell

Tannin cells were found in palisade layer immediately below the upper epidermis (Fig D). The number of tannin cells at unit length (1.1mm) showed significant difference between accessions. The average number ranged from 3.0 to 11.3 which was lowest in accessions of *A. hypogaea* and highest in *A. valida*. The number of tannin sacs is reported to be associated with rust resistance in peanut (Suryakumari *et al.* 1984).

Stem anatomy

Epidermis

The epidermis comprises single layered laterally elongated cells. The epidermal thickness ranges between 13.9 µm in ICG 8208 (*A. duranensis*) and 25.2 µm in ICG 8216 (*A. cardenasii*). *A. khulmannii* (ICG 8954) also showed thick epidermis (Table 4).

Cortex

Hexagonal parenchymatous cells constitute the cortex. The thickness ranges between 86 µm in ICG 8196 (*A. duranensis*) and 439 µm in *A. cardenasii*.

Vascular tissue

Vascular tissue provides both mechanical support and food and water translocation in plant system. ICG 8207 had very broad stellar tissue (686 µm) followed by ICG 8208; both belong to *A. duranensis*. The lowest value (204 µm) was recorded in ICG 8209 (*A. batizocoi*).

Pith

Pith tissue consists of hexagonal parenchymatous cells, which degenerate during the growth. At the age of 115 days, the pith tissue did not show any degeneration. The largest pith was observed in ICGS 8197 and 8135 (*A. monticola*) followed by ICG 8208 (*A. duranensis*). The lowest value was recorded in ICG 8139 (*A. duranensis*).

Tannin cells

The tannin cells were found only on the pith region just opposite to the protoxylem. The number against each protoxylem group varies between the species and accessions, which reflected in the total number of tannin cells. The average number at a cross section ranges between 13.0 and 47.7. In general, *A. hypogaea* accessions showed high number of tannin cells in pith. Among wild species ICG 8208 (*A. duranensis*) had the highest number (43.5) followed by ICG 8210 (*A. batizocoi*) and ICG 8957 (*A. duranensis*).

Bundle caps

These are made of sclerenchymatous cells that provide additional mechanical strength to the primary vascular tissue. Their number also indicates the number of primary vascular bundle. The average number ranges between 14.7 (ICG 8139) and 33.2 (ICG 8197). The distance between the bundle caps ranged between 37.3 µm in ICG 5813 (*A. hypogaea*) and 129.8 µm in *A. khulmannii*. Godoy *et al.* (1985) reported that the pod rot resistant genotypes were characterized by larger number of bundle caps, which were close to the outer surface of the stem.

Taxonomic relationship

Cluster analysis is frequently used to study the taxonomic relationship based on numerical data (Sneath and Sokal, 1973). Ravindran *et al.* (1997) used anatomical traits along with morphological characters in establishing

Table 4 Anatomical traits of cross section of stem of groundnut accessions

ICG No.	sep	sec	svt	sp	ntc	nbc	dbc
8124	17.6±0.7	100.0±0.0	464.0±5.8	924.0±5.8	21.9±0.2	24.5±0.2	50.6±1.4
8209	14.9±0.4	131.0±0.0	204.0±5.8	1357.0±25.2	17.3±0.3	21.7±0.1	100.3±2.3
8210	17.6±0.0	354.0±0.0	343.0±5.8	1516.0±5.8	41.2±0.2	25.1±0.2	115.9±4.9
8958	17.6±0.0	212.0±0.0	334.0±5.8	965.0±5.8	22.9±0.7	25.3±0.1	100.3±2.3
8216	25.2±0.4	439.0±0.0	592.0±0.0	1396.0±11.6	27.1±0.2	22.7±0.3	39.7±0.0
8132	18.1±0.4	129.0±0.0	459.0±0.0	922.0±37.9	28.1±0.2	25.7±0.1	50.6±1.4
8918	15.6±0.4	173.0±0.0	349.0±0.0	888.0±5.8	23.3±0.2	22.7±0.2	80.1±3.6
4983	15.2±0.4	133.6±5.8	619.0±10.0	1465.0±11.6	20.1±0.1	26.0±0.0	52.1±2.7
8123	18.8±2.8	156.0±0.0	229.0±0.0	847.0±15.3	21.1±0.4	16.1±0.3	55.2±1.4
8139	17.8±0.4	106.0±5.8	291.0±0.0	727.0±17.3	23.1±0.9	14.7±0.2	42.8±1.4
8196	15.6±0.4	86.0±5.8	248.0±5.8	773.0±5.8	13.0±0.2	18.3±0.2	82.4±2.7
8200	15.6±0.4	226.0±5.8	450.0±0.0	882.0±5.8	22.9±0.2	16.4±0.2	112.0±2.0
8201	17.6±0.7	165.0±5.8	284.0±5.8	1465.0±25.2	27.3±0.7	31.5±0.6	91.0±4.0
8205	15.2±0.4	156.0±5.8	345.0±5.8	1761.0±10.0	27.0±0.4	25.7±0.1	65.3±2.3
8207	17.6±0.7	124.0±5.8	686.0±5.8	618.0±5.77	25.4±0.0	17.9±0.3	59.1±1.4
8208	13.9±0.7	185.0±5.8	656.0±15.3	2025.0±11.6	43.5±0.6	25.5±0.1	84.8±4.9
8956	17.8±0.4	92.0±10.0	586.0±5.8	1157.0±15.3	27.0±0.6	21.3±0.3	73.1±1.4
8957	17.8±0.4	150.0±0.0	265.0±5.8	1137.0±10.0	40.6±0.5	27.5±0.2	63.6±1.4
8955	17.1±0.4	171.0±0.0	345.0±5.8	833.0±15.3	22.7±0.1	23.2±0.2	75.4±3.6
8190	17.6±0.0	214.0±0.0	332.0±0.0	1008.0±20.0	18.8±0.2	24.7±0.1	101.1±1.4
5813	17.1±0.4	154.0±5.8	456.0±5.8	1588.0±17.3	35.0±0.2	24.1±0.3	37.3±2.33
5770	15.6±0.4	221.0±0.0	362.0±5.8	2010.0±28.9	47.7±1.3	31.5±0.2	57.6±1.4
287	19.1±0.0	181.0±10.0	300.0±10.8	1798.0±11.6	36.7±1.8	28.9±0.4	88.7±6.2
3704	17.6±0.7	176.0±5.8	569.0±11.6	1733.0±5.8	33.1±0.2	24.2±0.0	45.1±1.4
8164	16.6±0.4	135.0±0.0	362.0±5.8	849.0±5.8	15.7±0.2	22.5±0.3	80.1±3.6
8959	17.6±0.0	149.0±5.8	369.0±10.0	884.0±5.87	28.7±1.5	22.8±0.4	87.9±2.7
8954	24.2±1.3	334.0±15.3	442.0±5.8	1143.0±15.3	21.0±0.6	16.5±0.1	129.9±1.4
8197	15.2±0.4	233.0±0.00	339.0±0.0	2347.0±15.3	20.7±0.4	33.2±3.1	49.8±1.4
8198	16.6±0.8	127.0±11.6	462.0±5.8	1447.0±10.0	20.5±0.5	25.2±0.5	73.1±3.6
8135	18.3±0.7	329.0±10.0	436.0±11.6	2188.0±25.2	28.7±0.1	29.4±0.2	98.8±4.9
8125	15.6±0.4	131.0±5.77	442.0±0.0	1253.0±30.0	18.1±0.2	25.6±0.2	82.4±3.6
8126	14.9±0.4	131.0±0.00	341.0±0.0	1453.0±0.0	20.0±0.2	25.7±0.1	78.6±3.6
8137	17.6±0.7	124.0±5.77	338.0±5.8	908.0±0.0	18.1±0.1	20.1±0.1	65.3±4.7
8906	17.8±0.4	131.0±0.00	578.0±0.0	1206.0±5.8	21.4±0.2	25.7±0.2	46.7±2.3
11548	19.3±0.4	130.0±10.0	342.0±5.8	1124.0±30.6	18.1±0.9	17.1±0.6	122.1±5.9

sep: Thickness of stem epidermis (μm), sec: Thickness of cortex (μm), ntc: No. of tannin cell in pith, svt: Thickness of vascular tissue (μm), nbc: No. of bundle caps, sp: Thickness of pith (μm), dbc: Distance between bundle caps (μm) relationship among 50 accessions of black pepper germplasm which revealed that thickness of epidermis, and leaf and stomatal characters played an important role in clustering genotypes and they contributed to the second principal component among the 22 traits studied including morphological traits.

In the present studies, the clustering based on 32 anatomical variables (23 observed and 9 calculated) resulted in the following grouping.

Cluster List of accessions

- I ICG 8124 (*A. Batizocoi*)
- II ICGs 8209, 8210, 8958 (*A. batizocoi*), **ICG 8200** (*A. duranensis*), ICG 11548
- III ICG 8126 (*A. cardenasii*)
- IV ICG 8207, ICG 8956 (*A. duranensis*) **and 8132**, 8918 (*A. correntina*) ICG 4983
- V ICGs 8196, 8123 and ICG 8139 (*A.* ***duranensis***)
- VI ICGs 8205, 8201 (*A. duranensis*)
- VII ICG 8208 (*A. duranensis*)
- VIII ICG 8957 (*A. duranensis*)
- IX ICG 8164 (*A. kempff-mercadoi*) and **ICG 8955 (*A. helodes*)**
- X ICG 8190 (*A. hoehnei*)
- XI ICGs 5813, 5770,287,3704 (*A. hypogaea*) and ICGs 8197, 8198, 8135
- XII ICG 8954 (*A. khulmannii*)
- XIII ICG 8125 (*A. stenosperma*)

At 13-cluster stage, all accessions of *A. hypogaea* and *A. monticola* combined to form a single cluster. Interestingly, the accessions belonging to different habit types independently clustered with *A. monticola* accessions viz., ICG 5770 with ICG 8135, ICG 3704 with ICG 8198 and ICG 287 with ICG 8906 before joining with accessions of the same species (Fig F). *A. duranensis* and *A. cardenasii* were found closely related to the cluster of tetrapoild species (*A. hypogaea* and *A. monticola*) and *A. stenosperma* was the most distantly related. The distribution of accessions of *A. duranensis* and *A. batizocoi* in different clusters indicates the wide variability of anatomical traits within the species. These results corroborate the studies on morphology (Stalker, 1990), isozymes polymorphism (Lacks and Stalker, 1993, Lu and Pickersgill, 1993) and DNA polymorphism (He *et al.* 1997). However, He *et al.* (1997) observed grouping of accessions from same geographical area in a single cluster based on similarity index of DNA fingerprints of *A. duranensis* and *A. stenosperma*.

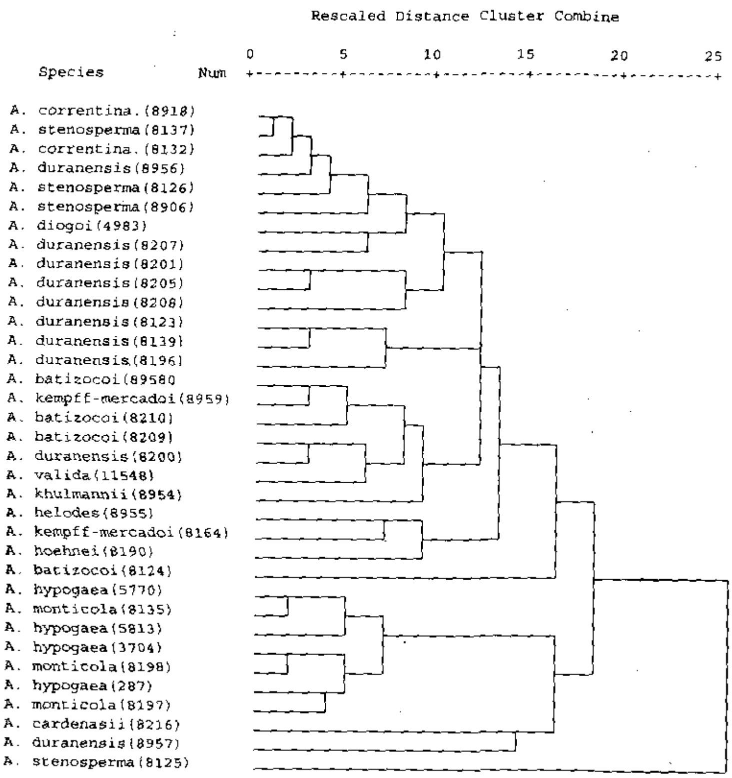

Fig F Dendrogram of 35 accessions of wild *Arachis* species

In the present study three of the four accessions of *A. duranensis* from Argentina found clustered together and the Bolivian collection did not show any such relationship. Though cytologically, *A. batizocoi* is very unique, the clustering based on anatomical traits showed that three accessions were closely related and grouped into one cluster and the one remained apart. *A. hoenei, A. cardenasii,* and *A. khulmannii* did not cluster with any other species at this level, however, only single representation was available for these species. Many anatomical traits, especially trichome density, trichome length, stomatal index, thickness of palisade layer, compactness in arrangement of palisade layer, thickness of the water storage layer, and number and depth of bundle caps in stem was reported to be contributing to various biotic and abiotic stresses. Hence, characterization based on anatomical traits will be helpful in preliminary screening of the germplasm at the laboratory level. Cluster analysis showed that the anatomical characters alone may not be useful for systematic studies and probably may contribute to delimiting the taxa at the species level along with other taxonomical traits.

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Inheritance of main stem flowering in groundnut (*Arachis hypogaea* L.)

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Abstract

Inheritance of main stem flowering (MSF) in groundnut was studied in six crosses, involving two parents with MSF and three without MSF. The segregation pattern in F_2 generation revealed that the main stem flowering was governed by two independent sets of duplicate loci interacting together with epistasis between loci. The genotypes of the five parents used in the study have been elucidated.

Key words : Groundnut, genetics, main stem flowering

Introduction

The cultivated species of groundnut (*Arachis hypogaea* L.) have been classified into two sub-species namely, *hypogaea* and *fastigiata*. The sub-species *fastigiata* has erect and bunch in habit, sequential branching , inflorescence usually present on the main stem and first branching on the cotyledonary laterals are reproductive, seed dormancy usually absent, light green foliage. It includes four varieties: var. *fastigiata*, var. *peruviana*, var. *aequatoriana* and var. *vulgaris* (Gregory *et al.*, 1951; Krapovickas; Gregory, 1994). The sub-species *hypogaea* has semi-spreading or spreading in habit, branching alternate, inflorescence simple and absent on main stem, seed dormancy usually present, foliage dark green, first branch on cotyledonary lateral always vegetative. It includes two varieties: var. *hypogaea* and var. *hirsute* (Gregory *et al.*, 1951). In intraspecific crosses, several intermediate types are observed which are of *hypogaea* type in growth habit but possess floral axils in main stem like *fastigiata*.

The reports in literature show that the main stem flowering trait is recessive in nature and is governed by single gene (Mouli *et al.*, 1986), and/or two sets of duplicate gene loci interacting epistasis with between loci (Hammons, 1971; Wynne, 1975). Hammons (1971) scheme of gene action assumes two sets of duplicate gene J_1/j_1; J_2/j_2 and K_1/k_1; K_2/k_2 in the control of main stem flowering. Further more, there is epistatic interaction between sets of J's and K's but no epistasis is present with J's and K's. Thus, with this sort of gene action, a heterozygote for all the four loci happens to exhibit 225 vegetative main stem leaf axils: 31 main stem flowering in F_2. The main stem flowering is expressed in recessive genotypes of either of the two gene sets J's or K's or both. Vegetative main stem leaf axil is expressed when atleast one dose of dominant allele of either of the J or K loci is present simultaneously. Present study was undertaken to confirm the genetic control of main stem flowering trait and to elucidate the genetic architecture with repsect to this trait in some of the Indian varieties of groundnut.

Material and methods

Two *fastigiata* cultivars, Chico and Girnar 1, were crossed as males to three *hypogaea* cultivars, ICGV 86325, CSMG 84-1 and GAUG 10 as females in *kharif* 1996. The resulting F_1's were raised during *kharif* 1997 at National Research Centre for Groundnut, Junagadh. The plants were harvested individually and F_2's of the six crosses were raised during *Kharif* 1998 in plant-to-progeny rows and were critically observed for presence or absence of flowering on main stem. The χ^2 test was applied to F_2 data to ascertain the segregation pattern. The multiplication ratio of groundnut is very low, so the progeny of the individual crosses were pooled together before applying the χ^2 test.

Results and discussion

All F_1 plants of the six crosses had vegetative leaf axils on the main stem and hence absence of main stem flowering was noticed. This confirmed the recessive nature of presence of reproductive axils on main stem and was in conformity with the observations of earlier workers (Hammons, 1971; Mouli *et al.*, 1986). Segregation of main stem flowering trait in different crosses in F_2's is given in table 1.

It is evident that F_2 segregation of main stem flowering varied in the families with both male and female parents used in the crosses (Table 1). Chico as a male parent produced 9:7; 225:31; and 3:1 ratios against ICGV

Table 1 The F_2 segregation of main stem flowering (MSF) in groundnut

Cross	Phenotype of F_1 plants	Number of F_2 phenotypes			Expected ratio	Probability	χ^2 value
		With MSF	Without MSF	Total			
ICGV 86325 x Chico	MSF	58	89	147	9:7	1.1015	0.25-0.50
ICGV 86325 x Girnar 1	MSF	63	160	223	3:1	1.2570	0.25-0.50
CSMG 84-1 x Chico	MSF	13	98	111	225:31(~7.25:1)	0.0005	0.95-0.99
CSMG 84-1 x Girnar 1	MSF	21	120	141	3:1	1.0269	0.25-0.50
GAUG 10 x Chico	MSF	34	107	141	3:1	0.0291	0.25-0.50
GAUG 10 x Girnar 1	MSF	18	130	148	225:31(~7.25:1)	0.0004	0.95-0.99

86325, CSMG 84-1 and GAUG 10 as female parents, respectively. Similarly, Girnar 1 as male parent exhibited 3:1 ratio with ICGV 86325 and CSMG 84-1 as female parent. The same male parent again produced 225:31 (7.25:1) ratio with GAUG 10 as female parent. It was clear that the genotypes of both male parents, Chico and Girnar 1, were different as they produced different F_2 ratios when the same set of female parents were used in the crosses. Similarly, all the female parents exhibited different F_2 ratios against common male parents. Thus, it may be concluded that all the male parents and so also the female parents used in this study were genotypically different from one another with respect to main stem flowering. Using the scheme of gene action proposed by Hammons (1971) the segregations in the present F_2's could very well be explained. Thus, using the gene symbols proposed hy Hammons (1971), the possible genotypes of these five parents used in this study could be j_1j_1 J_2J_2 k_1k_1 K_2K_2 (ICGV 86325), j_1j_1 j_2j_2 k_1k_1 k_2k_2 (CSMG 84-1); j_1j_1 j_2j_2 k_1k_1 k_2k_2 or recessive homozygote for any one of j or k loci (GAUG 10); j_1j_1 j_2j_2 k_1k_1 k_2k_2 (Chico); and j_1j_1 J_2J_2 k_1k_1 k_2k_2 or dominant homozygote for any one of the j or k loci (Girnar 1). All the F_2 ratios observed in the present study (3:1; 9:7; and 225:31) could be explained very conveniently assuming the proposed genotypes of the parents. Since the segregation pattern and the gene action observed in the present study were in conformity with those of Hammons (1971) and Wynne (1975), the gene symbol proposed by the former worker need not to be changed.

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Combining ability for seed yield and its components in linseed (*Linum usitatissimum* L.)

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Abstract

Twenty eight well adapted lines and two diverse testers of linseed (*Linum usitatissimum* L.)were crossed in L x T fashion to elicit information regarding the desirable parents and crosses for their use in breeding programme. The material was raised in RBD with three replications. Sufficient genetic variability was observed among the parents, lines and crosses. Based on general and specific combining variances, non additive gene action predominated for all the traits. Only 10 lines viz., B-509, LCK 89512, Giza-6, Neelam, Gaurav, KL-187, KL-188, Kiran, Flax purple and RL50-3 were identified good general combiners for yield and yield contributing characters, whereas 18 cross combinations were observed to be good specific combiners for these traits.

Key words : Line x tester, combining ability, non-additive gene action, seed fill, harvest index, linseed

Introduction

Genetic improvement aims at enhancing the yield in terms of economic product, a very complex trait. Seed yield in linseed is low in India in comparison to developed countries. To bring improvement in linseed, the research efforts made have mostly been directed towards individual plant selection in naturally varying land races and progeny selection followed by hybridization. However, varieties good in *per se* performance may not necessarily produce desirable progenies when used in hybridization. For the successful conduct of such research programme, the knowledge about the combining ability is important in the selection of suitable parents for hybridization, proper understanding of inheritance of quantitative traits and also in identifying the promising crosses for further use in breeding programmes. LxT besides providing information on the parents and crosses with respect to their combining abilities also furnish the knowledge about the suitable parents and breeding methodology to be adopted. The present investigation in linseed is undertaken with a view to identify the potential parents and promising crosses for their further use in breeding programme.

Materials and methods

The experimental material, consisting of 56 crosses in a line x tester design involving 28 diverse lines and two well adapted testers (*Kangra* local & *Nagarkot*) of linseed, was grown along with parents in a Randomized block design with three replications at HPKV, Palampur during 1998-99. Each plot consisted of one row of 3 m length with rows and plants spaced at 30 cm and 5 cm, respectively. All the recommended package of practices was used for raising the crop.

The observations for the characters *viz.*, grain yield/plant, 1000 grain weight, seeds per capsule, capsules per plant, tillers per plant, plant height, days to seed fill and harvest index were recorded on five competitive random plants in each plot, whereas for days to maturity, the data were recorded on plot basis. The analysis of variance and combining ability analysis were worked out as per the model devised by Sukhatme and Amble (1985) and Kempthorne (1957), respectively.

Results and discussion

The analysis of variance for L x T analysis (Table 1) revealed significant differences among the parents, lines and crosses for the characters studied. The mean squares due to testers were also significant for majority of the traits except for tillers per plant, seeds per capsule, maturity and harvest index. This showed the presence of

Table 1 Analysis of variance for different characters in linseed

Source	df	Grain yield/plant (g)	1000 grain weight (g)	Capsules/plant (No)	Seeds/capsule (No)	Tillers/plant (No)	Plant height (cm)	Days for Maturity	Days for Seed fill	Harvest index (%)
Parents	29	2.37*	7.39*	803.40*	1.00*	1.31*	389.49*	18.84*	111.62*	65.8*
Parents vs. Crosses	1	5.90*	6.10*	316.98*	0.19	0.30	570.88*	3.50	97.41*	137.30*
Crosses	55	1.21*	5.79*	309.33*	1.41*	0.60*	187.23	20.88*	97.32*	44.90*
Lines (Females)	27	2.51*	5.51*	840.19*	1.05*	1.40*	411.81*	20.16*	110.33*	70.51
Testers (Males)	1	0.63*	24.28*	171.74*	0.17	0.00	165.38*	1.49	54.00*	0.00
Line vs. *Tester*	1	0.52*	41.15*	441.80*	0.54*	0.02	10.81	0.42	204.00*	4.66
Error	170	0.05	0.01	9.88	0.13	0.08	12.61	6.00	10.39	3.36
$\sigma^2 gca$		0.01	0.67	15.18	0.02	0.01	3.18	0.01	1.57	-0.12
$\sigma^2 sca$		0.36	1.72	99.88	0.28	0.22	31.38	2.64	16.20	1.03
$\sigma^2 sca/gca$		0.36	2.56	6.58	14.50	22.00	9.86	2.64	10.31	8.58

* $P \geq 0.05$.

Table 2 Parents showing desirable *gca* effects for grain yield in linseed

Source	Grain yield/plant (g)	1000 grain weight (g)	Capsules/plant (No.)	Seeds/capsule (No.)	Tillers/*plant (No)*	Plant height (cm)	Days for Maturity	Days for Seed fill	Harvest index (%)
Lines									
KL-187	0.85*	1.91*	-0.39*	7.32	-	-	-	-3.42*	2.97*
KL-188	0.56	0.77*	-	4.57*	0.30*	-	-	-6.429	-
Giza - 6	0.44*	0.26*	-	16.15*	0.52*	9.52*	-	-9.42*	-
Kiran	1.15*	-1.06*	0.65*	10.02*	-	-11.93*	-	8.08*	6.69*
B-509	0.46*	0.34*	-0.49*	11.72*	0.35*	9.73*	-	-5.42*	-3.00*
Gaurav	0.26*	0.18*	-	6.42*	0.22*	5.22*	-	-	-3.40*
Neelam	0.50*	0.57*	-	-	-0.38*	-	-	-	3.59*
LCK-89512	0.62*	1.87*	0.69*	9.29*	0.39*	-	-	4.41*	2.81*
Flaxpurple	0.35*	-1.43*	0.65*	-2.81*	-	-	-	-	-
RL 50-3	0.26*	-	-	-	-	-5.02*	-	-	2.92*
SE ±	0.08	0.04	0.14	1.35	0.11	1.48	-	0.32	0.77
Testers									
Nagarkot	0.09*	0.63*	-0.11*	3.21*	-	1.18*	-	-0.86*	-0.11*
Kangra local	-0.09*	-0.63	0.11*	-3.21*	-	-1.18*	-	0.86*	0.11*
S.E. ±	0.023	0.010	0.04	0.36	0.04	0.39	0.27	0.35	0.21

* $P \geq 0.05$

sufficient genetic variability amongst the parents and crosses for the traits studied. The analysis of variance for combining ability also indicated sufficient variability for *gca* and *sca* among lines, testers and crosses. Based on *gca* and sca variances for combining ability, non-additive or both additive and non-additive gene actions prevailed for most of the traits. Therefore, it would be beneficial to develop a population by crossing these parents *inter se* before initiating random mating in F_2 to allow higher recombination. This is likely to break unfavourable linkages and confer a wide genetic base (Rawat, 1982).

Only ten lines out of 28 (Table 2) depicted desirable *gca* effects for grain yield and some of its contributing traits. These lines in order of their desirability were B-509, LCK 89512, Giza-6, Gaurav, Neelam, KL-187, KL-188, Kiran, Flax purple and RL 50-3. Each line was simultaneously good general combiner for two to six yield contributing traits. However, between testers *Nagarkot* was superior to *Kangra* local. Earlier workers like Pillai *et al.* (1995), Ratnaparkhi *et al.* (1998) and Mahto and Rahman (1998) also reported similar results for grain yield and its component traits in linseed using different genotypes. The differential behaviour of these lines with respect to *gca* effects for yield and various yield contributing characters might be the result of selection pressure subjected during the course of their evolution/development and the varying degrees of interaction between the yield and its components.

On the basis of *sca* effects, eighteen cross combinations (Table 3) showed desirable *sca* effects for grain yield in particular and its components, in general. These crosses can be exploited either by developing hybrids or by fixing desirable genes by way of suitable recombinant breeding. Although, CMS system in linseed as reported by Dubey and Singh (1966) indicates the possibility of commercial hybrid seed production, the suitable restorer and maintainer lines must be isolated for the effective exploitation of heterosis. The crosses showing desirable *sca* effects involved good x good, good x poor and good x average *gca* parents. This indicated that the desirable transgressive segregants may be released by the above crosses which may be further exploited in various breeding programmes.

Table 3 Cross combinations showing desirable *sca* effects for grain yield

Cross	Grain yield/plant (g)	1000 grain weight (g)	Capsule s/plant (No)	Seeds/ capsule (No)	Tillers/ plant (No)	Plant height (cm)	Days for		Harvest index (%)
							Maturity	Seed fill	
KL-188 x *Kangra* local	0.26*	0.73*	-	11.66*	0.42*	-	-	-	2.99*
Giza 6 x *Nagarkot*	0.84*	0.105*	-	14.89*	0.76*	-	-	-	-4.01*
Kiran x *Nagarkot*	1.29*	0.48*	-	19.36*	0.24*	-	-	-	-
B-509 x *Kangra* local	0.70*	1.31*	-0.45*	4.01*	0.81*	8.38*	-	-	3.10*
Giza-5 x *Kangra* local	0.24*	0.60	-	5.48*	-	-5.25*	-	-	2.31*
RLC-29 x *Nagarkot*	0.28*	-0.20*	-	-	-0.29*	5.60*	-	-7.30*	2.47*
Gaurav x *Nagarkot*	0.56*	0.57*	0.41*	4.42*	-	-	-	-	1.84*
Jeewan x *Nagarkot*	0.33*	0.72*	-	-	-	-	-	-	2.79*
LCK-89512 x *Kangra* local	0.27*	-	-	4.51*	0.24*	-	-	-	-
LCK-87132 x *Kangra* local	0.25*	-0.60*	-	-2.82*	-0.36*	-	-	-	2.16*
B-552 x *Nagarkot*	0.34*	0.22*	-	6.76*	-	5.35*	-4.42*	-	-
Flaxpurple x Kangra local	0.53*	0.29*	-	7.88*	-	-	-	-4.03*	-
Aoyagi x *Kangra* local	0.40*	-0.97*	0.42*	13.84*	0.47*	4.07*	-	-	2.57*
LC-54 x *Nagarkot*	0.46*	1.75*	0.42*	4.78*	-	-5.72*	-	-	-3.18
RLC-32 x *Kangra* local	0.46*	2.47*	-0.81*	3.84	-	-	-	-	1.84*
TLP-1 x *Kangra* local	0.24*	0.58*	-0.63*	-	-0.23*	-	-	-	-
KL-168 x *Kangra* local	0.31*	2.00*	-	-	0.24*	-	-	-	-
LCK-9436 x *Kangra* local	0.24*	-	-	6.14*	0.41*	-	-	-4.53*	-
S.E. ±	0.12	0.05	0.20	1.92	0.16	2.09	1.47	1.87	1.08

* $P \geq 0.05$

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Improvement of seed yield and quality through nutrient management in sunflower (*Helianthus annuus* L.)

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Abstract

A field experiment was conducted to study the effect of sulphur, boron and zinc on seed yield and quality of sunflower (*Helianthus annuus* L.). Among the various treatments tried, maximum seed yield (14.66 q ha^{-1}) was obtained with the combined application of sulphur @ 25 kg ha^{-1} + 0.2% boron spray at ray floret stage + 0.2% zinc spray at ray floret stage, closely followed by the combination of sulphur @ 25 kg ha^{-1} + 0.2% boron spray at ray floret stage (14.18 q ha^{-1}). This improvement in yield was attributed to increased head diameter, seed set percentage and test weight. Seed set percentage was significantly improved by boron application, while sulphur contributed to improvement in oil content. Besides improving the seed yield, the combination treatments were also beneficial in effecting better seed quality, maximum germination and seedling vigour index.

Key words : Sunflower, sulphur, boron, zinc, yield attributes, seed yield and quality

Introduction

Sunflower is an important oilseed crop and its cultivation has been widely attempted in the country. Though the crop has several advantages, some of the short comings are poor seed setting and large percentage of hollow seeds in its capitulum with poor germination. This problem demands greater attention due to its adverse effect on seed yield and quality of produce. Insufficient supply of macro and micronutrients seems to be one of the major causes for poor seed in sunflower.

Sulphur, an important secondary nutrient was essential to achieve maximum number of potential seeds (Hocking *et al.*, 1987) and played a key role in biosynthesis of oil. Among the micronutrients, boron appeared to have a special role in reproductive phase influencing the seed setting and filling (Blamey, 1976; Satyanarayana *et al.*, 1977). While, zinc was found essential for protein biosynthesis which helped in seed formation. An attempt has been made in the present study to assess the influence of sulphur, boron and zinc nutrition on seed yield and quality of hybrid sunflower.

Materials and methods

An experiment was conducted during *rabi*, 1995 at Agricultural College Farm, Rajendranagar, Hyderabad on red sandy loam soil under irrigated conditions. The soil of the experimental plots had a pH of 6.8, medium in available phosphorus, high in potassium and the available sulphur content was 8.9 ppm. The hot water soluble boron content ranged from 0.5 to 1.0 ppm. The parental lines of APSH-11 i.e. CMS 7-1A (Female) and RHA 271(Male) were sown in 3:1 ratio following a spacing of 60x30 cm in a randomised block design with three replications and the package of practices recommended for normal crop growth was followed.

The experiment consisted of nine treatments viz., soil application of sulphur (S) @ 25 kg ha^{-1} (T_1); 0.2% boron (B) spray at ray floret stage (r.f.s.) (T_2); 2 kg ha^{-1} B at r.f.s. (T_3); 0.2% zinc (Zn) spray at r.f.s. (T_4); T_2+T_4 (T_5); T_1 + T_2 (T_6); T_1 + T_3 (T_7); T_1 + T_2 + T_4 (T_8) and control (no sulphur, boron and zinc). Plants from one square meter area were taken to record data on seed yield and ancillary characters. Standard germination test was conducted and the product of per cent germination and the mean root and shoot length (cm) was taken as vigour index.

Results and discussion

The results on various yield contributory characters, seed yield and oil content are presented in table-1. In general all the treatments showed significant increase in seed yield over control. Maximum seed yield (14.66 q ha^{-1}) was recorded in case of T_8 (S @ 25 kg ha^{-1} + 0.2% B spray at r.f.s + 0.2% Zn spray at r.f.s) which was closely followed

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by T_6 (S @ 25 kg ha^{-1} + 0.2% B spray at r.f.s) but, there was no significant difference between the two treatments.

The enhanced seed yield with these treatments was mainly due to improvement in various yield contributory characters (Table-1). The treatments T_8 and T_6 were at par and recorded significantly higher seed set percentage of 84.5 and 84.9, respectively. These were also on par with the treatment T_2 (0.2% B spray at r.f.s) which recorded a seed set of 84.2%, indicating that increase in seed set percentage was mainly due to boron spray. Head diameter, the most important yield attributing character, which improved the seed yield by providing maximum number of florets for higher seed set was increased by 33.6 and 32.1 %, respectively by these two treatments i.e. T_8 (S @ 25 kg ha^{-1} + 0.2% B spray at r.f.s + 0.2% Zn spray at r.f.s.) and T_6 (S @ 25 kg ha^{-1} + 0.2% B spray at r.f.s.). The test weight (g) of seeds was also improved significantly over control in these two treatments.

Table 1 Effect of S,B, Zn and their combinations on yield components, seed yield and oil content of sunflower

Treatment	Head diameter (cm)	Seed set (%)	Total No. of seeds $head^{-1}$	Test weight (g)	Seed yield (q ha^{-1})	Oil content (%)
T_1 - Soil application of S @ 25 kg ha^{-1}	16.1	75.6	827.56	5.91	10.22	41.73
T_2 - 0.2% B spray at ray floret stage(rfs)	15.9	84.2	901.23	6.00	11.68	39.34
T_3 - 2 kg ha^{-1} B dusting at r.f.s	14.7	78.5	817.69	5.20	9.40	38.96
T_4 - 0.2% Zn spray at r.f.s.	13.8	76.7	743.36	4.92	8.21	40.44
T_5 -T_2 + T_4	16.0	83.3	891.23	6.22	12.14	40.81
T_6 - T_1 + T_2	17.7	84.5	936.73	6.46	14.18	41.52
T_7 - T_1 + T_3	16.2	79.5	857.56	6.12	11.00	41.18
T_8 - T_1 + T_2 +T_4	17.9	84.7	932.46	6.53	14.66	42.15
T_9 - Control (unsprayed)	13.4	72.6	708.26	4.20	6.95	38.05
SEm ±	0.60	0.80	5.06	0.142	0.90	0.388
CD (0.05)	1.67	2.33	15.17	0.424	1.15	1.148

Besides *improving the seed yield per hectare*, these two treatments were also beneficial in effecting better seed quality as evidenced by higher germination and vigour index (Fig. 1). The treatment T_8 (S @ 25 kg ha^{-1} + 0.2% B spray at r.f.s + 0.2% Zn spray at r.f.s.) recorded maximum germination and seedling vigour index compared to all other treatments.

The data on oil content in seed also followed similar trends under different treatments as noted for seed yield. The oil content ranged from 38.05 to 42.15 % for various treatments. Maximum oil content of 42.15 % was observed in the combination treatment of S @ 25 kg ha^{-1} + 0.2% B *spray at* r.f.s. + *0.2% Zn spray at r.f.s.*(T_8) and it was at par with all the other treatments where sulphur was included (Table 1). These results were in agreement with that of Shukla *et al.*, (1983). Sulphur helped in conversion of carbohydrates to oil (Chopra and Kanwar, 1966) and it also played an important role in fatty acid synthesis by converting acetyl Co-A to malonys Co-A. This might be one of the reason for increased oil content of sunflower with sulphur application.

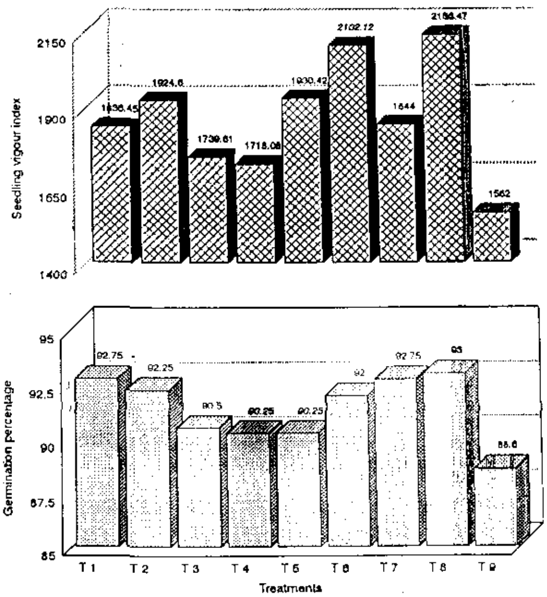

Fig 1 Effect of S, B, Zn and their combination on germination percentage and seedling vigour index

In the present investigation, though the treatments T_8 and T_6 were at par regarding seed yield, when quality aspect is considered T_8 is significantly superior to T_6. Since quality seed is considered as the vital input for enhancing and stabilizing the productivity of crop, the treatment T_8 is recommended for enhancing the crop productivity and quality of sunflower.

Among the methods of application of boron, spraying at ray floret stage was found to be significantly superior to dusting in all the yield attributes and seed yield. This might be due to increased availability of boron at a faster rate due to foliar spray as compared to dusting.

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Effect of copper application on leghemoglobin, grain yield and quality of soybean (*Glycine max* L.) in mollisols of Uttar Pradesh*

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Abstract

A field experiment was conducted during the *kharif* 1997 and 1998 at the Crop Research Centre, Pantnagar, to study the effect of copper application on nodule leghemoglobin content, grain yield and quality of soybean (*Glycine max* L.). Sixteen treatment combinations consisting of four varieties (Bragg, PK 262, PK 416 and PK 1042) and four copper levels (0, 2.5, 5 and 10 kg Cu ha^{-1}) were tested in split plot design with three replications. Soybean varieties differed significantly in their copper requirement in terms of nodule leghemoglobin content, grain yield, protein and oil content. The variety, PK 416 showed an increased trend of these characters and can be grown in soils containing high available copper, while Bragg was sensitive. Copper @ 2.5 kg ha^{-1} significantly increased the leghemoglobin content in nodules both at 45 and 60 days. Application of copper did not increase the grain yield significantly in both years but interactions between varieties and copper levels for grain yield were significant. The variety, PK 416 consistently out yielded other varieties and gave the highest grain yield at 5 kg Cu ha^{-1} (1785 kg ha^{-1}) and Bragg yielded the lowest. Application of 2.5 and 5 kg Cu ha^{-1} significantly increased grain protein and oil content during 1997 and 1998 resulting in 4.30 and 9.69, 1.92 and 4.82 % increase over control.

Key words : Copper nutrition, soybean, grain yield, leghemoglobin, protein, oil content

Introduction

Soybean with 40-42 % protein and 20-22 % oil has already emerged as one of the major rainy season cash crops in Uttar Pradesh. Copper is established as an essential plant micro nutrient both for legume and root nodule bacteria. Due to continuous growing of legumes, regular application of super phosphate and nitrogenous fertilizers, the native copper content in soils, often becomes inadequate (Gartrell, 1981) for crop nutrition. Plants receiving higher levels of copper in the nutrients have larger nodules, enhanced symbiotic nitrogen fixation (Greenwood and Hallsworth, 1960) in subterranean clover and also increased leghemoglobin content, grain yield and nitrogen content in lupin (Seliga, 1993) and fababean (Abdel Wahab *et al.*, 1996). This necessitated to evaluate the response of different soybean varieties in mollisols of northern India to copper nutrition.

Materials and methods

The experiment was conducted during the rainy season of 1997 and 1998 at the Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The soil of the experimental field was silty clay loam of mollisol having pH of 7.3 with organic carbon 0.81 %, available nitrogen 325 kg N ha^{-1}, phosphorous (Olsen's P) 10.5 kg P ha^{-1} and potassium 132 kg K ha^{-1}. The 0.005 M DTPA-extractable copper (Lindsay and Norvell, 1978) and total copper (digestion with hydrofluric-perchloric acids) were 0.87 and 48.13 ppm respectively.

The experiment was laid out in split-plot design with three replications of plot size 6 m x 3.6 m. Sixteen treatment combinations comprising four varieties (Bragg, PK 262, PK 416 and PK 1042) as main plot and four copper levels (0, 2.5, 5 and 10 kg Cu ha^{-1}) were tested as sub-plot treatments. Copper was applied as copper sulphate commercial grade ($CuSO_4$, $5H_2O$) at sowing and thoroughly mixed in 0-15 cm soil. Soybean varieties were inoculated at the rate of 500 g *Bradyrhizobium japonicum* culture per 75 kg seed. Leghemoglobin content of fresh nodules was estimated by colorimetric procedure (Proctor, 1963). The grain yield of net plot at 14 % moisture was reported as yield kg ha^{-1}. The crude protein of soybean

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grains at harvest was worked out by multiplying the N content of grain analyzed by micro-Kjeldahl method with a standard factor 6.25. Oil in soybean grain was extracted in soxhlet as ether extractable (boiling point 40°C to 60°C).

Results and discussion

Leghemoglobin content

The leghemoglobin content increased with the advancement of crop age and reached its peak at 60 days after sowing (Table 1). The pooled results indicated that *there was a significant increase in* leghemoglobin content in nodules due to copper application both at 45 and 60 days. The variety, PK 416 had the highest and Bragg contained the lowest leghemoglobin content. Again, PK 416 was at par with that of PK 1042 at 60 days. Application of 2.5 and 5 kg Cu ha^{-1} significantly increased the leghemoglobin content in nodules showing 28.1 and 20.0, 24.6 and 10.7 % increase over control at 45 and 60 days after sowing, respectively. In the present study, leghemoglobin content showed positive (r=0.695) and highly significant (P<0.01) correlation with grain yield at 60 days. This result closely agreed with findings of Prasad and Ram (1988) in mungbean (*Vigna radiata* L., Wilczek) and Seliga (1993) in Lupins (*Lupinus luteus* L.) that copper application has a stimulating effect on the synthesis of leghemoglobin in the root nodules. Several workers have also reported that plant receiving higher levels of copper in the nutrients had larger nodules, increased their numbers and enhanced its fixation (Hallsworth *et al.*, 1964) because copper raised the efficiency of energy producing systems, essential for metabolites directly involved in N_2 fixation and is a co-factor of enzymes involved in N_2 fixation and increase the nitrogen uptake (Snowbell *et al.*, 1980). Leghemoglobin is known for maintenance of low oxygen tension within the nodule cells and considered a pre-requisite for nitrogen fixation as it is generally correlated with N_2fixation because leghemoglobin content is an index of the volume of the active tissue. Cartwright and Hallsworth (1970) reported that copper deficiency on root nodules of subterranean clover caused a depression of the bacterial content, an accumulation of starch in invaded cells and a reduction in the rate of development of the nodule apex. They further suggested that low activity of copper containing enzymes (e.g. cytochroma C oxidase) *might be important* for maintenance of low oxygen tension within the nodule cells essential for nitrogen fixing activity. The result indicated that leghemoglobin, the characteristic red pigment of soybean root nodules, is clearly dependent on adequate supply of copper for its synthesis.

Table1 Effect of copper application on leghemoglobin content in root nodules of soybean (Pooled data of 1997 and 1998)

Treatment	Leghemoglobin content (mg/g nodule fresh weight)	
	45 DAS	60 DAS
Varieties		
Bragg	9.99	25.46
PK 262	22.14	34.52
PK 416	30.03	36.86
PK 1042	28.08	36.06
SEm±	0.54	0.48
CD (0.05)	1.86	1.40
Copper levels (kg Cu ha^{-1})		
0	19.80	31.69
2.5	25.37	38.03
5.0	24.67	35.09
10.0	20.40	27.82
SEm±	0.59	0.96
CD 0.05)	1.73	2.80

Grain yield

During both the years, highest grain yield was recorded in PK 416 which was significantly greater than rest of the varieties (Table 2). Grain yield of PK 1042 was also significantly higher than PK 262 and Bragg. Minimum yield was recorded in Bragg. The differences in grain yield due to copper levels were non-significant, however, interaction effects between varieties and copper levels were significant during both the years as well as in pooled data (Table 3). The pooled results showed that PK 416 produced consistently at par at all copper levels and gave highest grain yield at 5 kg Cu ha^{-1} which was significantly higher than all other varieties at same or different copper levels. The grain yield of variety PK 262 at 2.5 kg Cu ha^{-1} was significantly the highest when compared with other levels of copper interestingly it was at par with PK 1042 and were significantly higher than Bragg. Minimum grain yield was recorded in Bragg. Oplinger and Ohlrogge (1974) also reported similar increase in soybean grain yield due to copper application. Again increase in grain yield in PK 416 with copper application presumably associated with an increase in the quantity of nitrogen fixed by the nodules, because copper application in this study resulted in more leghemoglobin content in nodules and also has positive relationship with grain yield.

Protein content

Protein content of PK 416 was highest and significantly greater than PK 1042 which contained lowest grain protein during both the years (Table 2). However, differences between PK 416 and PK 262 for grain protein content were non-significant. This indicated that genotypic variability exists for the differences in the grain protein content (Mutschler *et al.*, 1980). In this study, application of 5 kg Cu ha^{-1} resulted in maximum grain protein showing 11.6 and 7.2 % increase over control during 1997 and 1998, respectively. However, there was significant increase in grain protein at all copper levels over control. These results supported the conclusion of Rasheed and Seeley (1966) that copper in plant is associated with protein metabolism. Therefore, copper application resulted in maximum grain protein which might have the associated effect from better N_2fixed by the nodules, that increased the grain nitrogen content and ultimately protein content in the grain.

Oil content

Varietal comparisons revealed that oil content of PK 416 was highest followed by PK 1042 and PK 262. The results clearly showed that there was significant increase in oil content at all copper levels over control. Maximum oil content was recorded with the application of 5 kg Cu ha^{-1} which gave significantly 5.4 and 3.7, 4.1 and 2.1, 4.8 and 2.8 % higher oil yield than control and 2.5 kg Cu ha^{-1} during 1997, 1998 and in pooled respectively and remained statistically at par with 10 kg Cu ha^{-1}. Marschner (1995) *reported that plants deficient in copper* in the nutrient medium play a direct role by reducing the enzymatic activities in the synthesis of oil or an indirect *role by preventing the accumulation of sufficient* carbohydrate reserve for maximum oil formation, because copper participated in carbohydrate metabolism and also functions in desaturation process during oil synthesis.

Table 2 Grain yield, protein and oil content of soybean at harvest as influenced by different varieties and copper levels

Treatment	Grain yield (kg/ha)			Protein content (%)			Oil content (%)		
	1997	1998	Pooled	1997	1998	Pooled	1997	1998	Pooled
Varieties									
Bragg	986	910	948	40.95	40.71	40.83	18.73	18.78	18.74
PK 262	1319	993	1156	40.90	42.19	41.54	19.72	19.87	19.80
PK 416	1979	1415	1683	41.38	42.33	41.85	20.75	20.80	20.78
PK 1042	1590	1130	1360	39.71	38.83	39.27	20.12	19.95	20.03
SEm±	84	46	48	0.33	0.09	0.15	0.20	0.23	0.21
CD (0.05)	290	160	169	0.98	0.31	0.54	0.68	0.80	0.71
Copper levels (kg Cu ha^{-1})									
0	1424	1122	1273	38.42	39.59	39.00	19.26	19.38	19.31
2.5	1479	1149	1314	41.00	40.36	40.68	19.58	19.76	19.68
5.0	1535	1069	1288	42.90	42.65	42.78	20.31	20.17	20.24
10.0	1437	1108	1273	40.63	41.45	41.04	20.16	20.08	20.12
SEm±	46	43	32	0.27	0.17	0.13	0.01	0.09	0.08
CD (0.05)	NS	NS	NS	0.78	0.51	0.39	0.28	0.28	0.25
V x Cu	Sig	Sig	Sig						

NS : Not significant, Sig : Significant

Table 3 Effect of interaction between varieties and copper levels on grain yield (kg ha^{-1}) of soybean (Pooled data of 1997 and 1998)

Varieties	Copper levels (kg Cu ha^{-1})			
	0	2.5	5.0	10.0
Bragg	1080	880	921	913
PK 262	1108	1387	1038	1092
PK 416	1633	1669	1785	1647
PK 1042	1271	1322	1409	1440

	SEm±	CD (0.05)
For comparing two copper levels at same variety	64	187
For comparing two varieties at same or different levels of copper	80	233

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Effect of irrigation regimes and nitrogen on water use efficiency and moisture extraction pattern by soybean (*Glycine max* L.)

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Abstract

Field experiments were conducted on clay loam soil at Rajasthan College of Agriculture, Udaipur during *Kharif* 1993 and 1994 to study the effect of irrigation regimes and nitrogen levels on water use and moisture extraction pattern by Soybean. The seasonal consumptive use, water use efficiency and daily rate of water use by Soybean crop were maximum with (0.8 IW/CPE) ratio. The values were minimum under no irrigation treatment. The seasonal consumptive use was greater during 1993 compared to 1994. The contribution towards consumptive use under higher irrigation regime was maximum from the top soil layer (0-15 cm) followed by 15-30 cm and minimum from deeper layer (45-60 cm). Contrary to this, the relative depletion of soil moisture was maximum from deeper soil layer (45-60 cm depth) under lower irrigation regime of 0.4 IW/CPE and rainfed treatment. The seed yield of soybean increased significantly with increase in nitrogen level up to 60 kg/ha. The seasonal consumptive use, water use efficiency and moisture extraction pattern by soybean crop were not affected significantly due to increasing nitrogen levels.

Key words : Soybean, irrigation regime, nitrogen, water use efficiency, moisture extraction pattern

Introduction

In India Soybean is generally grown in monsoon season as either rainfed or under limited available irrigation. Due to aberrant and insufficient rainfall during crop growing season the crop invariably suffers moisture stress to different degrees and duration's especially at reproductive growth. Scott *et al.* (1986) reported that full season irrigation increased the average yield of Soybean by 39.7 to 49.7 % in normal rainfall year whereas, 70.1 to 79.1 % in dry year. Further, they reported that irrigation after onset of reproductive growth increased yield of Soybean by 16.9 to 17.4 %, respectively.

Since, Soybean seeds are very rich in protein (40%) and oil (20%), the higher nitrogen requirement for growth and development are not met fully by the plant through symbiosis. Tanaka (1986) also reported high N-requirement of Soybean crop. It is even essential for nodule formation and development of legume seedling before N-fixation begins (Subba Rao, 1976). Under Indian conditions, Soybean crop has shown positive response to N-application upto 60 kg/ha (Hasnabade *et al.*, 1990; Reddy *et al.*, 1990). While in some cases, response has been obtained upto 100 kg N/ha (Naidu and Pillai, 1991). Further, it is very well established that efficiency of fertilizer use depends largely on efficient water management and *vice-versa*. Since, both these factors have regional specificity as optimum irrigation regime is tied with prevailing weather parameters just as optimum fertilization is related to nutrient supplying capacity of the soils. The information on these aspects of the crop management specially for sub-humid southern plain and Aravalli hills Zone (IVa) of Rajasthan State is lacking and hence, this experiment was conducted.

Materials and methods

A field experiment was conducted for two consecutive *Kharif* seasons of 1993 and 1994 at the instructional farm, Rajasthan College of Agriculture, Udaipur. The soil of the experimental site was clay loam in texture (sand 40.68%, silt 23.30% and clay 36.02%), analyzing medium in total nitrogen (0.07%), available phosphorus (17.0 kg/ha) and rich in available potash (296.30 kg/ha) with pH 8.28. Field capacity and permanent wilting points were 23.30% and 11.51%, respectively in 0-30 cm soil layer and the bulk density in the same layer was 1.42 g/cc. The soils of Udaipur region fall under the soil order Alfisols. The treatments comprised five irrigation regimes (irrigation at

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IW/CPE ratios of 0.4, 0.6 and 0.8 and at crop growth stages along with control) and four nitrogen levels (24, 40, 60 and 80 kg N/ha). These twenty treatment combinations were replicated four times in split plot design, keeping irrigation regimes in main plot and nitrogen levels in sub plot. The IW/CPE ratios were maintained by scheduling irrigation at cumulative pan evaporimeter (CPE) values of 150, 100 and 75 mm, respectively keeping depth of irrigation water (IW) as 60mm. Cumulative pan evaporation value was taken as a sum of daily evaporation from USWB Class "A" open pan evaporimeter minus precipitation from the date of previous irrigation. The effective rainfall (ER) was estimated by the standard formulae advocated by Misra and Ahmed (1990). Irrigation at crop growth stages (branching/flowering, pod filling and dough) was applied whenever, moisture stress was noticed. In rainfed treatment, no water was allowed to enter from adjoining plots and individual plot was separated by buffer channels. The required amount of water measured through constant head flow method was applied at each irrigation, keeping irrigation efficiency as 80 % (Table-1). A uniform dose of 50 kg P_2O_5/ha and nitrogen levels (treatment wise) were applied in furrows before sowing. Soybean cv. Gaurav was used as test crop and sowing was done in rows 30 cm apart using seed rate of 80 kg/ha on 4th July and 28th June, during 1993 and 1994, respectively. In the first year 443.2 mm rainfall was received in 19 rainy days whereas, in second year 668.6 mm rainfall was received in 38 rainy days during crop growth period.

Table 1 **Details of irrigation under different irrigation regimes**

Treatment	Number of irrigations		Total quantity applied (mm)*	
	1993	1994	1993	1994
Irrigation regimes (I)				
No irrigation - 0	--	--	443.2	668.6
0.41 IW/CPE - 1	2	**	563.2	-
0.6 IW/CPE - 2	3	1	623.2	728.6
0.8 IW/CPE - 3	4	2	683.2	788.6
Crop growth stages - 4	4	2	683.2	788.6

* Including rainfall 443.2 mm in 1993 and 668.6 mm in 1994 during crop growth period.

** No irrigation applied as the ratio of IW/CPE 0.4 did not reach in 1994 during crop growth period.

In order to study the moisture extraction pattern, a levelled spot in the middle of each plot was selected and its centre was marked with a stake. The soil samples within a radius of about 50 cm. from the centre, were collected for soil moisture determination from the successive layers of 0-15, 15-30, 30-45 and 45-60 cm. depth by the thermo gravimetric method at sowing, before and after 48 hrs., of each irrigation and at harvest. The seasonal consumptive use of water, water use efficiency, daily rate of water use and moisture extraction pattern, were computed as per the standard procedure.

Results and discussion

Seasonal consumptive use

Seasonal consumptive use (CU) of water by soybean progressively increased with increase in irrigation regime based either on increment in IW/CPE ratio from 0.4 to 0.8 or irrigation at crop growth stages, though significant difference was noted between high irrigation regime and rainfed treatment during 1993 only (Table-2). The maximum seasonal CU during 1993 was under irrigation regime I_3 (466.41 mm) while during 1994 the value was highest with irrigation at crop growth stages (394.80 mm). The minimum seasonal CU was recorded under no irrigation treatment both during 1993 and 1994 with mean value of 318.7 mm. The increase in consumptive use with increasing moisture regimes might be on account of bringing conditions more conductive for potential evapotranspiration (PET) by frequent wetting of soil surface and continuous water loss at increased rate for longer time under high irrigation regime (Table-2). The findings of present study are in accordance with Scott et al. (1986), Rajput et al. (1991) and Martin et al. (1994). The seasonal CU by soybean when compared within the years, more values were recorded more during 1993 compared to 1994 under high irrigation regimes and vice-versa under rainfed treatment (Table-2). This might be due to low rainfall and high temperature during 1993, resulting in high evaporation of water from surface and transpiration by plants, as water was not the limiting factor under high irrigation regimes. Whereas, under rainfed treatment soil moisture is the limiting factor, hence less water loss from surface of soil. Seasonal CU was not influenced significantly with increasing nitrogen levels from 20 to 80 kg/ha during both the years, though, increased marginally upto 60 kg N/ha. The highest seasonal CU of 422.45 and 381.88 mm was observed under 60 kg N/ha. during 1993 and 1994, respectively. This might be because of higher root growth under efficient N level (60 kg N/ha).

Water use efficiency

Both field water use efficiency (EU) and crop water use efficiency (ECU) were maximum at 0.4 IW/CPE and decreased with increasing irrigation regime from 0.6 to 0.8 IW/CPE and/or at crop growth stages during 1993 whereas, during 1994 the values of EU and ECU increased gradually with increase in irrigation regime. However, mean data revealed that the maximum values for EU and ECU were observed at 0.8 IW/CPE ratio (13),

Table 2 Effect of irrigation *regimes and nitrogen* levels in soybean

Treatment	Consumptive use (mm)			Water use efficiency (kg/mm/ha) EU			ECU			Daily water use rate (mm/day)			Days to crop maturity			Seed yield (q/ha)		
	1993	1994	Mean	1993	1994	Mean	1993	1994	Mean	1993	1994	Mean	1993	1994	Mean	1993	1994	Mean
Irrigation regime																		
No irrigation	301.11	335.63	318.37	3.05	3.30	3.18	3.94	4.60	4.27	2.96	3.06	3.01	101.6	109.6	105.6	11.86	15.45	13.66
0.4 IW/CPE	396.18	-	-	3.46	-	-	4.46	-	-	3.81	-	-	104.0	-	-	17.69	-	-
0.6 IW/COE	425.56	357.88	391.72	3.17	3.24	3.21	4.25	4.79	4.52	4.05	3.15	3.60	104.9	113.6	109.3	18.05	17.52	17.79
0.8 IW/CPE	466.41	382.22	424.32	3.15	3.50	3.33	4.25	5.38	4.82	4.42	3.34	3.88	105.5	116.4	110.9	19.80	20.58	20.19
Growth stages	452.64	394.80	423.72	2.88	3.42	3.15	4.00	5.09	4.55	4.29	3.46	3.88	105.5	116.1	110.8	18.11	21.10	19.11
S.Em+	42.56	32.67	-	0.32	0.28	-	0.17	0.26	-	0.33	0.28	-	0.48	0.56	-	0.68	0.60	-
CD (0.05)	131.64	NS	-	NS	NS	-	0.52	NS	-	1.02	NS	-	1.49	1.79	-	2.10	1.92	-
Nirogen levels																		
20 kg/ha	393.44	355.02	374.23	2.83	3.17	3.00	3.79	4.74	4.27	3.77	3.16	3.47	104.3	113.4	108.8	14.92	16.83	15.88
40 kg/ha	404.38	368.90	386.64	3.05	3.36	3.21	4.07	4.95	4.51	3.88	3.27	3.58	104.3	113.9	109.1	16.46	18.27	17.37
60 kg/ha	422.45	381.68	402.07	3.35	3.52	3.44	4.43	5.15	4.79	4.05	3.37	3.71	104.4	114.4	109.4	18.71	19.68	19.20
80 kg/ha	413.25	364.93	389.09	3.34	3.42	3.38	4.43	5.06	4.75	3.96	3.22	3.59	104.4	114.4	109.4	18.32	18.47	18.40
S.Em+	22.23	20.45	-	0.23	0.17	-	0.10	0.16	-	0.19	0.16	-	0.14	0.30	-	0.50	0.48	-
CD (0.05)	NS	NS	-	NS	NS	-	0.29	NS	-	NS	NS	-	NS	NS	-	1.43	1.39	-

ECU = Crop water use efficiency. EU = Field water use efficiency estimating 3.33 and 4.82 kg/mm/ha, respectively while, the minimum ECU was recorded under no irrigation treatment (I_0). The marked improvement in WUE might be due to greater increase in seed yield with relatively smaller increase in consumptive use and *vice-versa* under reduced water use efficiency. These results are in close conformity with the findings of Mousavi *et al.* (1988).

Both field and crop water use efficiency marginally increased with increasing N rates up to 60 kg/ha. Further increase in N levels had declining effect on both field and crop water use efficiency. The highest EU and ECU value of 3.44 and 4.79 kg/mm/ha., respectively were obtained under 60 kg N/ha as against the minimum values of 3.50 and 4.27 kg/mm/ha observed under rainfed treatment.

Daily water use rate

The daily water use rate significantly increased with increasing irrigation regimes from 0.6 to 0.8 IW/CPE and/or at growth stages over no irrigation treatment during 1993 only (Table-2). The maximum rate of daily water use was witnessed under irrigation regimes I_3 and I_4 during respective years of 1993 and 1994 and the minimum rate (3.01 mm/day) was recorded under no irrigation treatment (I_0). The rate of daily water use substantially increased with increase in irrigation frequency at higher irrigation regimes, due to higher moisture availability for evapo-transpiration. Garside *et al.* (1992) and Martin *et al.* (1994) also reported increased rate of ET with increase in level of soil moisture.

Daily water use rate was maximum with application of 60 kg N/ha and the value was minimum with (20 kgN/ha) during both the years of research, however, failed to gain statistical significance. Further increase in N rates from 60 to 80 kg/ha has resulted in slight decline in daily water use rate.

Moisture extraction pattern

Under wet irrigation regimes (I_3 and I_4) soil moisture depletion was maximum from upper most soil layer (0-15 cm depth) followed by 15-30 cm depth. Depletion of soil moisture declined gradually with further increase in soil depth and the minimum depletion was found from 45-60 cm depth (Fig 1). However, soil moisture depletion from upper soil layer increased gradually with lower irrigation regime (I_2 and I_1) and the lowest was recorded in no irrigation treatment (I_0), while the reverse trend was noticed from lower soil layers. The highest depletion of water from upper soil layer under wet irrigation regime could be due to more water availability for evaporation at soil surface which might have increased absorption and inturn transpiration by the plants. Whereas, under drier irrigation regimes and no irrigation treatment, availability of water and consequently absorption was reduced due to drying of upper layers, hence depletion of moisture from lower layers increased to meet the demand. The results are in agreement with the findings of Hutchinson *et al.*, (1984) and Garside *et al.*, (1992).

Under high irrigation regimes, the relative contribution of soil moisture depletion towards seasonal consumptive use was maximum from the upper soil layer (0-15 cm depth) and it decreased successively with increase in soil depth, and the lowest was recorded from deeper soil layer of 45-60 cm depth (Fig 1). Contrary to this, the relative contribution was more from deeper soil layer and lesser from upper layers as observed under lower irrigation regime and rainfed control. This might be probably due to larger root system which developed in search of water in deeper layers under dry irrigation regime and rainfed treatment. Whereas, under wet irrigation regimes the density of root system was more in upper layers. Moisture depletion pattern was not affected significantly due to application of nitrogen at varied levels.

The results in the present study clearly brought out that irrigation at IW/CPE ratio 0.8 and application of 60 kg N/ha improved the seasonal consumptive use, water use efficiency and seed yield of soybean. Further, irrigating the soybean crop at critical growth stages was found equally effective with that of 0.8IW/CPE in respect of seasonal consumptive use, water use efficiency and seed yield.

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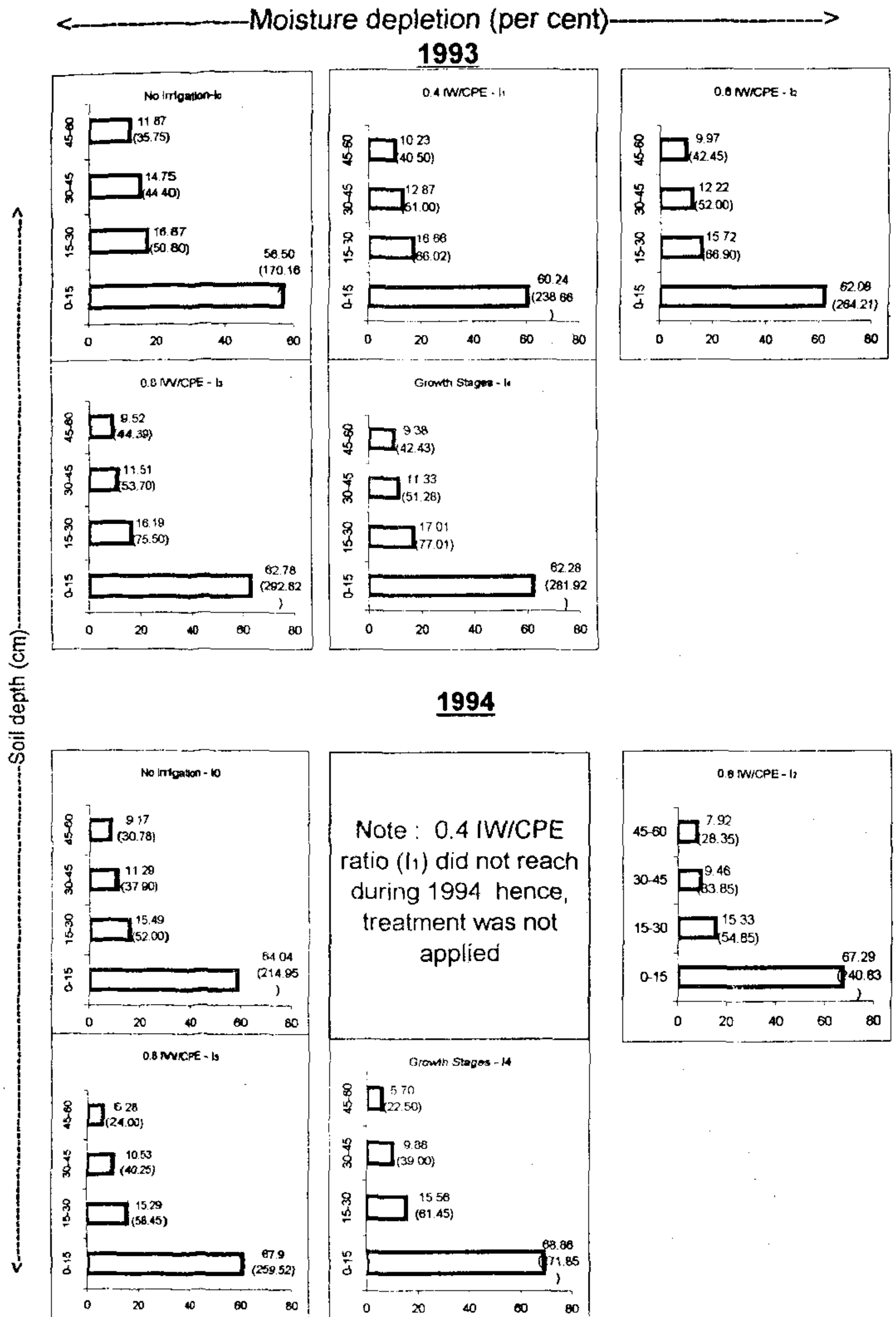

Figure -2 Effect of irrigation regimes on soil-moisture depletion from different soil layers. {Figures in parentheses indicate water use (mm)}

Fig 1 Effect of irrigation regimes on soil-moisture depletion from different soil layers Figures in parenthesis indicate water use (mm)

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Effect of spacing and sowing date on the productivity of sunflower (*Helianthus annuus* L.)

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Abstract

Field studies were conducted at the OUAT Regional Research Station, Chiplima, Sambalpur during winter seasons of 1993-94 and 1994-95 to find out the optimum spacing and time of sowing for sunflower. Crop with row spacing of 45 cm yielded significantly more than that of 60 cm. Yield did not vary markedly due to plant spacings of 30, 25 and 20 cm indicating that wider spacing of 30 cm can be commercially adopted. The highest seed yield was obtained with a spacing of 45 cm x 30 cm. Sowing the crop on 16 December was the best in terms of yield. Earlier sowing on 16 October and 1 November also recorded identical seed yield, but delayed sowing on 30 December and 16 January reduced the yield significantly.

Key words : Sunflower, spacing, date of sowing.

Introduction

Sunflower crop has been recently attracting the attention of the farmers of Orissa, owing to its high yielding ability and wide adaptability to growing season. Being photo and thermo-insensitive, sunflower can be sown all the year round and as such can fit in well in the multiple cropping systems. However, this crop responds differently to varying seeding dates in a particular season (Habeebullah *et al.*, 1983). Scanty agronomic information is available about this crop under varying agro-climatic conditions. The present experiment was therefore conducted to find out the optimum spacing and date of sowing for obtaining higher yield of sunflower.

Materials and methods

An experiment was conducted at the OUAT Regional Research Station, Chiplima, Sambalpur, during winter season of 1993-94 and 1994-95. The treatments comprised six spacings during the first year and five dates of sowing with two selected spacings during the second year. The layout was in randomized block design with three replications. The soil of the experimental plot was sandy loam with pH 6.2, total N 0.06% and available P and K of 15.3 and 195.8 kg/ha, respectively. Variety Morden was grown with uniform fertilizer dose of 60 kg N, 45 kg P_2O_5 and 30 kg K_2O/ha in form of urea, single super phosphate and muriate of potash, respectively. Full dose of phosphorus and potash along with 50% N was applied at the time of sowing and the rest 50% N was applied at the time of interculture three weeks after sowing. The crop was sown on 18 January and harvested on 19 April during 1993-94. During the second year sowing and harvesting dates varied as per the treatment. Irrigation was provided to the crop as and when required. The crop was kept free from insect pests and diseases through suitable plant protection measures.

Results and discussion

Growth duration

Maturity of sunflower varied due to date of sowing but remained unaffected by spacing (Table 1). The crop sown on 16 October took 100 days to mature and the duration decreased progressively with successive delay in sowing. For each fortnight delay in sowing from 16 October, the duration of the crop on an average was reduced by two days and the crop sown on 16 January matured in only 85 days.

Table 1 **Effect of sowing date and spacing on growth duration of sunflower (1994-95)**

Treatment	Days taken to maturity
Date of sowing	
16 October	100
1 November	98
16 December	91
30 December	89
16 January	85
Spacing (cm)	
45 x 30	92.6
45 x 20	92.6

Growth and yield attributes

Plant height did not vary markedly due to spacing (Table 2). Head diameter during the second year was significantly more with wider spacing of 45cm x 30cm than with the closer spacing of 45cm x 20cm (Table 3). During the first year, head diameter, though did not vary significantly due to spacing, wider spacing of 60cm x 30cm produced larger heads than the closer spacings. Number of filled seeds per head and the 1000-seed weight were the maximum with 45cm x 30cm spacing followed by 60cm x 30cm spacing. All the closer spacings reduced the number of filled seeds per head and 1000-seed weight, the reduction, being statistically significant only during the first year.

Date of sowing has influenced all the yield attributes significantly. Sowing the crop on 16 January with 45cm x 30cm spacing produced the tallest plants. Earlier sowing, in general significantly reduced the plant height, which might be due to prevailing low temperature in vegetative stage of the crop. Head diameter of the crop sown on 30 December and 16 January with 45cm x 30cm spacing was the maximum. Earlier sowing reduced the head diameter significantly. Number of filled seeds per head was maximum due to sowing on 16 December with 45cm x 30cm spacing. Earlier sowing on 16 October and 1 November produced identical number of filled seeds per head but delayed sowing on 30 December and 16 January reduced the number of filled seeds per head significantly. Test weight of the seeds was higher due to sowing on 16 October with 45cm x 30cm spacing. There was progressive decline in the test weight of seeds due to successive delay in sowing. Sterility percentage was more under wider spacing and delayed sowing.

Yield

Row spacing of 45 cm recorded significantly more seed yield than 60 cm spacing, irrespective of the plant spacing (Table 2). The average seed yield with 45 cm row spacing was 12.7 q/ha as against 6.30 q/ha with 60 cm row spacing, the reduction in yield due to wider spacing being 49%. Yield did not vary due to row spacing of 30 cm, 25 cm and 20 cm under row spacing of 45 cm. During the second year also seed yield did not vary significantly due to the plant spacing of 30 cm and 20 cm irrespective of the date of sowing. Average seed yield with 45 cm x 30 cm spacing was 7.03 q/ha and that with 45 cm x 20 cm spacing was 7.22 q/ha. Hence it is advantageous to sow the crop with a spacing of 45 cm x 30 cm to achieve economy on seed and labour. The results are in agreement with Sarmah *et al.* (1992), who reported from Hisar highest seed yield of sunflower with a planting density of 7.4 plants/m^2. Both higher and lower planting densities reduced the seed yield significantly.

Table 2 Effect of spacing on yield attributes and yield of sunflower (1993-94)

Spacing (cm)	Plant height (cm)	Head diameter (cm)	Filled seeds/ head	1000-seed weight (g)	Seed yield (q/ha)
60 x 30	148.4	11.1	523	37.8	5.90
60 x 25	151.0	10.9	458	36.1	6.00
60 x 20	156.9	10.8	425	33.2	7.00
45 x 30	165.4	11.1	528	42.0	12.6
45 x 25	157.4	10.2	467	36.6	12.7
45 x 20	154.7	9.9	446	33.8	12.9
CD (0.05)	NS	NS	27	1.5	0.41

Table 3 Effect of date of sowing and spacing on yield attributes and yield of sunflower (1994-95)

Treatment Days x spacing (cm)		Plant height (cm)	Head diameter (cm)	Filled seeds/ head	Unfilled achenes/ head	1000-seed weight (g)	Seed yield (q/ha)
16 Oct.	45 x 30	107.7	13.8	349	243	53.3	9.12
	45 x 20	104.7	10.4	341	187	47.7	8.38
1 Nov.	45 x 30	109.9	13.5	369	298	44.1	8.01
	45 x 20	110.0	11.8	314	191	41.1	9.13
16 Dec.	45 x 30	124.4	13.7	391	202	41.8	8.81
	45 x 20	117.0	12.3	353	196	39.4	10.28
30 Dec.	45 x 30	117.7	16.3	252	378	41.6	5.25
	45 x 20	111.3	12.4	202	266	34.0	5.14
16 Jan.	45 x 30	129.8	15.5	216	398	37.0	3.96
	45 x 20	120.8	13.1	152	285	31.0	3.19
CD (0.05)		10.8	1.3	77	131	9.9	2.36

Date of sowing influenced the seed yield significantly. Sowing the crop on 16 December recorded the highest seed yield. Earlier sowing on 16 October and 1 November irrespective of the row spacing recorded identical seed yield, but delayed sowing on 30 December and 16 January reduced the seed yield significantly, and the reduction, on an average due to 15 and 30 days delay in sowing from 16 December was 45 and 62%, respectively, which might be due to reduced number of filled seeds per head, increased sterility percentage and reduced test weight of seeds. The results are in concurrence with those of Jadhav *et al.* (1991) and Patil *et al.* (1989) who reported from Rahuri that the seed yield of sunflower decreased significantly as the sowing was delayed beyond 21 September during winter and beyond 2 March during summer season.

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Status of inorganic 'P' fractions in alfisol after harvest of sunflower (*Helianthus annuus* L.)

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Abstract

An experiment was conducted during *rabi*, 1995-96 to study the extent of depletion of inorganic P fractions by sunflower (*Helianthus annuus* L.) grown on Alfisol of medium P status. Application of P at different levels resulted in increase in contents of P fractions over control. In control plots, the pattern of depletion followed the sequence Al-P > S-P > RS-P > Fe-P > Ca-P with values of 13.21, 12.22, 3.18. 2.13 and 0.98 % at harvest of sunflower, respectively. The total sum of inorganic P fractions showed positive correlation (0.987*) with the available P content at harvest of the crop.

Key words : Sunflower, P fractions, depletion.

Introduction

Sunflower is grown in more than two million hectares in India and is gaining popularity with time. In Andhra Pradesh, during 1996-97 it was grown in 0.30 million hectares with a production of 0.21 million tonnes (Directorate of Economics and Statistics, 1998). Sunflower, being an exhaustive crop by nature, needs better soil fertility than other oilseed crops. Though the effects of applied N, P and K on yields of sunflower were extensively studied, the extent of depletion of their fractions from soil was not attempted by many. Phosphorus is one of the major limiting plant nutrients, next to nitrogen in most of soils. On an average, the quantities of P_2O_5 required to produce a tonne of yield are 2 kg for tubers, 10 kg for cereals, 14 kg for pulses and 24 kg for oilseeds. Realising the importance of P in nutrition of oilseed crops, a study was conducted to understand the pattern of depletion of inorganic P fractions by sunflower grown on Alfisol.

Materials and methods

A field experiment was conducted during *rabi*, 1995-96 with sunflower (cv. Morden) as the test crop. The soil of experimental plot was a sandy loam (Alfisol) with a pH of 7.3. It was non saline (EC - 0.02 d Sm^{-1}). The contents of available N, P_2O_5 and K_2O were 112, 13.5 and 304 kg ha^{-1}, respectively. The status of inorganic P fractions in soil before the start of experiment was 1.8, 26.5, 34.2, 35.6 and 30.8 ppm for S-P, Al-P, Fe-P, Ca-P and RS-P, respectively. Phosphorus was applied at 5 levels viz., 0(P_0), 25(P_{25}), 50(P_{50}), 75(P_{75}) and 100(P_{100}) kg P_2O_5 ha^{-1}. The experiment was laid out in a RBD with each treatment replicated four times. Phosphorus was applied through SSP as basal as per the treatments. Post-harvest soil samples were collected, air dried, passed through 2 mm sieve and were analysed for contents of available P (Olsen *et al.*, 1954) and its inorganic fractions (Chang and Jackson, 1957).

Results and discussion

Application of phosphorus to sunflower crop resulted in changed status of different inorganic P fractions (Table 1).

Saloid-P : Significant increase in status of saloid-P was observed in soil at harvest of sunflower treated with different levels of phosphorus over control. The S-P contents of 1.58, 2.08, 2.63, 2.79 and 3.08 ppm were recorded in treatments P_0, P_{25}, P_{50}, P_{75} and P_{100}, respectively (Table 1). In control, the S-P content recorded after harvest was much less than the initial status (1.8 ppm) of soil.

Aluminium-P: The mean aluminium-P observed at harvest of sunflower was 33.12 ppm, which was greater than the initial Al-P status by 25 %. The content of A1-P recorded in each treatment varied significantly showing the effect of levels of applied P on this P fraction in soil.

Iron-P: The Fe-P contents recorded at harvest of sunflower in treatments P_0 (33.47 ppm) and P_{25} (33.93 ppm) were lower than the initial status of Fe-P (34.2 ppm). However, Fe-P contents at harvest of sunflower varied significantly among P_{50} to P_{100} levels of applied P.

Table 1 Effect of levels of phosphorus on status of inorganic P fractions at harvest of sunflower (*rabi*, 1995-96)

Treatment	Content (ppm)					Available P ($kg\ P_2O_5\ ha^{-1}$)
	S - P	Al - P	Fe - P	Ca - P	RS - P	
P_0	1.58	23.00	33.47	35.25	29.82	13.35
P_{25}	2.08	27.36	33.93	38.77	35.07	19.18
P_{50}	2.63	33.46	38.61	42.70	40.24	28.79
P_{75}	2.79	37.22	44.64	48.80	43.89	39.45
P_{100}	3.08	44.80	46.66	54.73	49.78	54.88
Mean	2.43	33.17	39.46	44.07	39.76	31.13
S.Em±	0.04	0.38	0.38	0.34	0.45	0.36
C.D.(0.05)	0.13	1.16	1.18	1.04	1.39	1.10

Calcium-P: Application of different levels of P to sunflower significantly influenced the Ca-P content in soil at all levels of added P. The highest Ca-P content was observed in treatment P_{100} i.e., 54.73 ppm, while the least was recorded in P_0 i.e., 35.25 ppm.

Reductant soluble-P: The RS-P content of 29.82, 37.07, 40.24, 43.84 and 49.78 ppm were observed at P_0, P_{25}, P_{50}, P_{75} and P_{100} levels of applied P, respectively.

Available-P: The available P contents varied from 13.35 to 54.88 kg $P_2O_5\ ha^{-1}$, the lowest being observed in P_0 while the highest was noticed in P_{100}. The increase in content of available P was the highest between P_{75} and P_{100} (15.43 kg $P_2O_5\ ha^{-1}$).

The data on extent of depletion of these fractions in control plots are given in table 2. Among the P fractions, depletion of Al-P from soil was the highest by sunflower at harvest. The pattern of depletion followed the sequence. Al-P > S-P > RS-P > Fe-P > Ca-P with values 13.21, 12.22, 3.18, 2.13 and 0.98 %, respectively (Table 2). However, at P_{25}, the contents of all P fractions increased over that of the initial status except that of Fe-P, indicating that when soil P was the only source of P (P_0), the sunflower crop depended more on Al-P whereas when fertilizer P was also made available, the uptake by the crop was more from the Fe-P. This also indicates that the applied P is immediately converted to Fe-P in Alfisol and it later on got converted to Al-P after sometime which the crop absorbed subsequently. Comparing the preferences of cereal, pulse and oilseed crops grown in a local Alfisol, Rao *et al*. (1984) observed that sunflower depleted Al-P followed by Ca-P and RS-P in that order.

When the mean available P_2O_5 status of treated plots was related to the individual fractions, positive correlations were observed with values of 0.862**, 0.952**, 0.983**, 0.979** and 0.923** in case of S-P, Al-P, Fe-P, Ca-P and RS-P, respectively. Even the total sum of the fractions showed positive relationship (r=0.987*) with this parameter. These observations indicated that all the P fractions are contributing to the available P pool when P was applied to soil.

Table 2 Depletion of P fractions from control plots at harvest of sunflower

P fraction	P content (ppm)		Depletion (%)
	Initial	After sunflower	
S - P	1.80	1.58	12.22
Al - P	26.50	23.00	13.21
Fe - P	34.20	33.47	2.13
Ca - P	35.60	35.25	0.98
RS - P	30.80	29.82	3.18

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Crop coefficients for sunflower (*Helianthus annuus* L.) as influenced by water deficit at different crop growth subperiods

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Abstract

A field experiment was conducted during 1995-96 and 1996-97 winter season on a sandy loam soil to derive crop coefficients and irrigation requirements for sunflower. The fully irrigated control treatment recorded significantly higher crop coefficient (Kc) values at all the crop growth subperiods in comparison to other treatments. The variation of Kc values was largely a function of actual evapotranspiration (Eta) deficit at different crop growth sub-periods and leaf area of the crop. The crop coefficient curve for fully irrigated treatment showed that the Kc value was low (0.385) in the establishment period, increased linearly through vegetative period, and attained a peak value of 1.049 during flowering, seed formation and seed filling period (25-96 DAS). Over the penultimate crop-growth subperiod of *maturity (99-105 DAS)* the Kc value decreased to a low value of 0.564. The field application of this study revealed that the net and gross irrigation requirements at field inlet and head works were 5469.9 and 9572.2 m^3, respectively.

Key words : Sunflower, crop coefficients, evapotranspiration deficit, irrigation requirements.

Introduction

Sunflower is an important winter oilseed crop of Andhra Pradesh cultivated under irrigated conditions. However, very limited information is available on water requirements (evapo-transpiration) of sunflower. With continuous and rapid expansion in area under this crop in canal-command areas, such an information is essential for determining water requirement in a region for scheduling proper irrigation. Experimentally derived crop coefficients can be used for estimating crop water requirements at progressive stages of crop growth for a given location from the estimates of reference crop evapotranspiration (Praveen Rao and Raikhelkar, 1994). This study was therefore conducted to derive crop coefficients of sunflower for the entire crop-growing season under variable water supply. Also, methodology for calculation of irrigation requirements was suggested.

Materials and methods

The field experiment was conducted at the college farm at Rajendranagar, Hyderabad (17.19°N, 78.23°E and 543 m above mean sea level) in winter season of 1995-96 and 1996-97 on a sandy loam soil. The N, P_2O_5, and K_2O contents of experimental soil were 270, 18.2 and 508 kg/ha, respectively, with pH 7.5, bulk density 1.66g/cm^3 and EC 0.13 dS/m. The available soil determined as difference between moisture held at-0.03 MPa and -1.5 MPa was 84.4 mm in 60 cm soil profile.

The field experiment constituted seven irrigation treatments designed to allow moderate to severe evapotranspiration (Eta) deficits to develop in one or more crop growth sub-periods (Table 1). In any given growth sub-period, the crop was either irrigated (W) based on soil-crop-climatic data (Praveen Rao, 1993) to ensure Eta proceeded at the potential rate (Etm) or it was not irrigated (D) at all (Table 1). Following an Etd at the end of the crop growth sub-period in water deficit treatment, the root zone depth of the crop was replenished to filed capacity moisture content. The seven treatments were laidout in randomized block design with four replications. A 50 mm water meter was installed to deliver the required quantity of water in each plot. "MSFH-8" sunflower hybrid was sown on 30th October both in 1995-96 and 1996-97, respectively by adopting a spacing of 45 x 30 cm to achieve a desired plant population of 74,100 plants/ha. The soil moisture was monitored by gravimetric method at four locations at 0-60 cm depths in each treatment before and after each irrigation, so also on intermediate dates as necessary. The reference crop evapotranspiration (Eto) was estimated at specific crop growth sub-periods based on Hargreaves method (Hargreaves and Samani, 1982).

Table 1 **Details of irrigation treatments for sunflower**

Treatment designation GS1-GS2-GS3	Description
W - W - W	Irrigation at Eta/Etm=1 throughout the crop growing season
D - W - W	Withholding of irrigation (Eta deficit) at vegetative period (0-30 DAS)
W - D - W	Withholding of irrigation (Eta deficit) at flowering and seed formation period (30-60 DAS)
W - W - D	Withholding of irrigation (Eta deficit) at seed filling period (60-105 DAS)
D - D - W	Withholding of irrigation (Eta deficit) at vegetative period plus flowering and seed formation period (0-60 DAS)
W - D - D	Withholding of irrigation (Eta deficit) at flowering and seed formation period plus seed filling period (30-105 DAS)
D - W - D	Withholding of irrigation (Eta deficit) at vegetative period (0-30 DAS) plus seed filling period (60-105 DAS)

GS1-Vegetative Period; GS2-Flowering and Seed Formation Period; GS3-Seed Filling period; Eta-Actual Evapotranspiration

Etm-Maximum Evapotranspiration

Thus the data obtained on Eta of sunflower crop and Eto at specific crop growth sub-periods were used to calculate the crop coefficient (Kc) as follows :

Kc = Eta/Eto **(1)**

For constructing the crop coefficient curve (Fig.1) the crop life of sunflower was divided into establishment, vegetative, flowering and seed formation, seed filling and ripening and maturity sub-periods. The crop in W-W-W treatment, which produced Kc values (Fig 1), was irrigated seven times. To use the Kc values for predicting crop Eta (Eta=Kc.Eto) throughout the crop season.

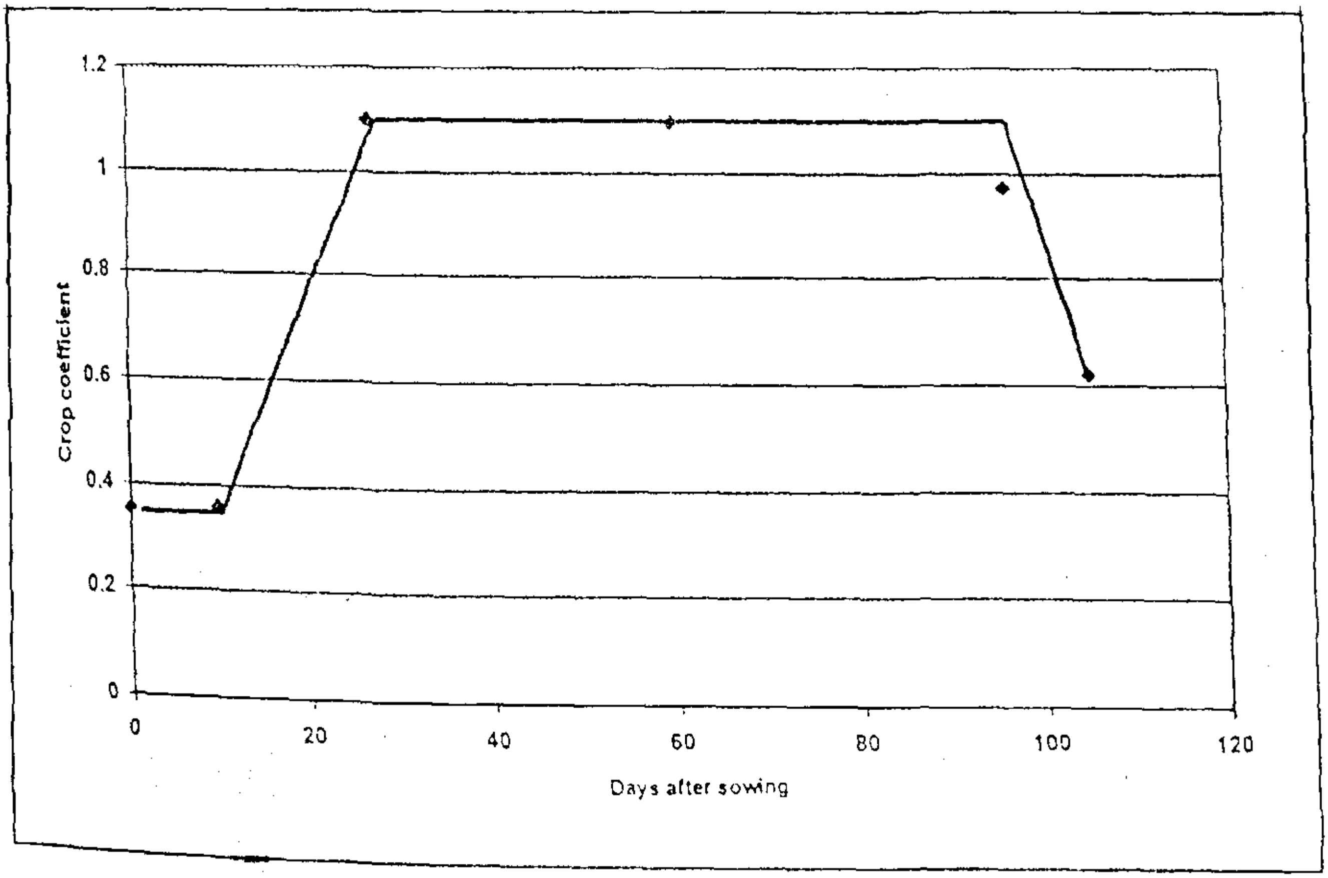

Fig 1 Crop coefficient curves of sunflower

As an application of this study in water management, the estimates of Eta for sunflower crop from the Kc values of irrigation treatment (W-W-W) were used to determine the actual irrigation requirements for a given design as follows:

In = Eta x Growth period in days (2)

Where, In, net irrigation requirement (mm) for the growth period considered and Eta, evapotranspiration of the crop (mm/day).

V at field inlet = [10/Ea] x [A.In/1-LR] m^3 (3)

V at head work = [10/Ep] x [A.In/1-LR] m^3 (4)

Where, V = gross irrigation requirement for the period considered (m^3); Ea = field application efficiency (0.7); A = area (1 ha); In = net irrigation requirement (mm); LR = Leaching requirement (nil); and Ep = project efficiency (0.4).

Results and discussion

Effect of water deficits on Kc values

Perusal of the variation of Kc values indicated that W-W-W treatment registered the highest Kc value of 1.041 and 1.057 during the first and second year, respectively at flowering and seed formation period (Table 2). Likewise the treatment D-W-W with Eta deficits at vegetative period *alone though registered a low value initially*, recovered remarkably with water supply at later crop growth sub-periods of flowering and seed formation plus seed filling periods and attained a peak value of 1.015 (1995-96) and 0.998 (1996-97) comparable to W-W-W treatment. The Kc values in W-W-D treatment first increased with time to 1.003 in the first year and 1.004 in the second year at flowering and seed formation period and then with further increase in time, the Kc value decreased to 0.697 (1995-96) and 0.651 (1996-97) at seed filling period and to 0.193 (1995-96) and 0.149 (1996-97) at maturity due to with-holding of irrigations at seed filling period. The variation of Kc value with time in D-W-D treatment exhibited trend almost similar to W-W-D inspite of Eta deficits both at vegetative period plus seed filling period. In W-D-W treatment with Eta deficits only at flowering and seed formation period, the Kc value remained lower than W-W-W, D-W-W and W-W-D treatments from flowering to begining of seed filling period. Adequate water supply at seed filling period in W-D-W treatment did not improve the Kc value markedly at later stages. The treatment D-D-W with Eta deficit both at vegetative period plus flowering and seed formation period registered lower Kc value initially in both the years but with adequate water supply at seed filling period it increased to a peak value of 0.779 and 0.714 in the first and second year, respectively, but decreased again towards maturity. The W-D-D treatment with Eta deficit from flowering to maturity though recorded higher Kc value than D-D-W treatment at vegetative period and beginning of flowering and seed formation period, it precipitously decreased at latter stages to a low value, which varied between 0.111 and 0.116 in the first year and 0.097 and 0.138 in the second year.

Crop coefficient curve

The crop coefficient curve shown in Fig.1 was drawn in such a way that the numerical deviation from the data points was minimum. The average Kc values for W-W-W treatment varied between 0.385 to 1.049 during crop life. Initially the Kc value was low (0.385) due to incomplete canopy cover (63.9 cm^2) reflecting that most of the water loss may constitute evaporation from bare soil, while germination, emergence and establishment of the crop took place. With advancement of crop age, the Kc value increased to 0.777 reflecting the increased transpiring surface (773 cm^2) as a consequence of rapid leaf development. During flowering, seed formation and seed filling period the Kc value reached to 1.049 indicating the peak water requirement of the crop as a consequence of full canopy cover (3373.7 cm^2), intercepting maximum incident radiation. Over the penultimate crop-growth subperiod of maturity (99-105 DAS) the Kc value decreased to a low of 0.564 due to leaf senescence.

Table 2 Crop coefficients of sunflower as influenced by evapotranspiration deficits at different crop growth subperiods

Treatment	Crop growth subperiods									
	Establishment (0-10 DAS)		Vegetative (11-27 DAS)		Flowering and seed formation (28-60 DAS)		Seed filling and ripening		Maturity (99-105 DAS)	
	1995-96	1996-97	1995-96	1996-97	1995-96	1996-97	1995-96	1996-97	1995-96	1996-97
W-W-W	0.409	0.361	0.758	0.796	1.041	1.057	0.954	0.890	0.568	0.559
D-W-W	0.398	0.345	0.558	0.582	1.015	0.998	0.905	0.843	0.528	0.524
W-D-W	0.369	0.357	0.716	0.744	0.539	0.508	0.841	0.797	0.560	0.494
W-W-D	0.389	0.353	0.738	0.780	1.003	1.004	0.697	0.651	0.193	0.149
D-D-W	0.407	0.355	0.513	0.548	0.516	0.492	0.779	0.714	0.580	0.577
W-D-D	0.391	0.355	0.728	0.761	0.476	0.462	0.101	0.097	0.116	0.138
D-W-D	0.404	0.340	0.516	0.590	0.984	1.011	0.654	0.617	0.180	0.119

Irrigation requirements

The net irrigation requirement (In) was low (18.11 mm) in the establishment period (Table 3), increased linearly during vegetative to 61.24 mm and then to a peak value of 172.76 mm at flowering and seed formation period. Thereafter it decreased linearly to a value of 108mm at seed filling period and finally to 22.78 mm at maturity period. The seasonal In was 382.89 mm.

The gross irrigation requirement (V) showed trend similar to In with crop ontogeny. The V varied from 258.7 to 2468 m^3 at field inlet and from 452.7 to 4319 m^3 at headwork. The seasonal V amounted to 5469.9 m^3 at field inlet and 9572.2 m^3 at headwork. The higher V value at head work in comparison to field inlet was attributed to low project efficiency (Ep).

Thus it is concluded that the crop Kc values derived in the present study for sunflower would facilitate estimation of crop Eta, which in turn can be used in determining net and gross irrigation requirements of crop for developing optimal operational schedule of irrigation applications to sunflower.

Table 3 Net (In) and gross irrigation requirement (V) for sunflower

Parameter	Crop growth subperiods					
	Establishment (0-10 DAS)	Vegetative (11-27 DAS)	Flowering and seed formation (28-60 DAS)	Seed filling and ripening (61-98 DAS)	Maturity (99-105 days)	Total growing season (0-105 DAS)
Eto (mm/day)	4.705	5.256	4.706	3.254	4.490	4.270
Kc value	0.385	0.777	1.049	0.922	0.564	0.854
Etm (mm/day)	1.811	4.083	4.936	3.000	2.532	3.646
In (mm/period)	18.11	61.24	172.76	108.00	22.78	382.89
V at field inlet (m^3)	258.7	874.9	2468.0	1542.90	325.43	5469.9
V at head work (m^3)	452.7	1531.0	4319.0	2700.0	569.5	9572.2
Peak irrigation requirement (m^3)						4319.0

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Performance of pre-monsoon crops and *kharif* groundnut under rainfed alfisols of southern agro-climatic zone of Andhra Pradesh

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Abstract

Four crops (green gram, cowpea, sesame and sunflower) were tested at three dates of seeding (7th, 18th and 27th May) followed by *kharif* groundnut in rainfed Alfisols. Sesame among the crops and 7th May seeding among the dates resulted in higher groundnut equivalents. Interaction of 7th May seeded sesame resulted in highest groundnut pod yield equivalents of 1101 kg/ha. Total yield advantage was higher (1168 kg/ha) with the sequence of pre-monsoon sesame and *kharif* groundnut. Net monetary returns were higher (Rs. 9915/ha) with the double crop sequence of pre-monsoon sesame seeded on 7th May followed by *kharif* groundnut.

Key words : Pre-monsoon, groundnut, double cropping, economics

Introduction

Increasing cropping intensity under rainfed conditions brings in higher production, income, employment and conservation of soil. Seventy eight per cent of the soils in southern agro-climatic zone of Andhra Pradesh are Alfisols with low moisture retention for profitable crop production under rainfed conditions. The normal rainfall of 990 mm with a bimodal distribution in the zone can support double cropping if suitable crops/varieties are selected. Investigations at Regional Agricultural Research Station, Tirupati indicated the possibility of raising a short duration second crop such as green gram, horse gram, cowpea, cluster bean, sesame and sunflower after rainy season groundnut. But successful completion of these crops was risky with early withdrawal of North-East monsoon (RARS, 1980). Markov-chain analysis of rainfall pattern indicated clear prospect of 9-10 weeks of growing period prior to regular *kharif* groundnut. The present investigation was taken up to evaluate short duration crops and their sowing time in pre-monsoon season to facilitate the sowing of groundnut in normal season.

Materials and methods

The field experiment was carried out during pre-monsoon and *kharif* seasons of 1994 at the Tirupati campus of Acharya N.G. Ranga Agricultural University in a randomized block design with factorial concept and replicated thrice. The soil was sandy loam in texture and low in available nitrogen (130 kg/ha), medium in available P_2O_5 (26 kg/ha) and K_2O (160 kg/ha). The treatment combinations consisted of four crops viz., sesame (Madhavi), cowpea (C-152) green gram (ML 267) and sunflower (Morden) each seeded on 7th, 18th and 27th May. All the crops were raised using their recommended seed rates and fertilizer doses and harvested as per their maturity. Seventh and 27th May seeded crops were irrigated immediately after sowing as the rainfall was inadequate for germination. Groundnut was sown immediately after the harvest of each of the four crops tested as pre-monsoon crops for the first two dates. As the sowing time of *kharif* groundnut was delayed after third date of seeding of green gram, cowpea and sunflower, groundnut was not taken up after these crops, while all the three dates of sowing of sesame followed groundnut sowing. Hence statistical analysis was not attempted to pod yield of groundnut. Groundnut was sown on 13.8.94 in 7th May seeded cowpea and sesame plots and on 18.8.94 in 7th May sown green gram and sunflower plots and also in 18th and 27th May seeded sesame plots. In rest of the plots except in 18th May sown sunflower plot in which groundnut was sown on 1.9.1994, the sowing of groundnut was done on 24.8.1994. Yields of all the pre-monsoon crops were converted into groundnut pod equivalents for easy comparison.

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Groundnut pod equivalents of pre-monsoon crops (kg/ha) =

$$\frac{\text{Grain yield of pre-monsoon crop (kg/ha)} \times \text{Unit cost of pre-monsoon crop (Rs/kg)}}{\text{Unit cost of groundnut pods (Rs/kg)}}$$

For evaluating the system, the total yield for each treatment was calculated by adding groundnut pod equivalents of each treatment to its respective pod yield of groundnut. Economic analysis was carried out to identify crop sequence options. The benefit cost ratio of the sequence was worked out taking prevailing market prices of crops.

Table 1 Groundnut pod equivalents of pre-monsoon crops (kg/ha), pod yield of groundnut (kg/ha) and total system yield (kg/ha)

Date of seeding of premonsoon crop	Green gram	Cowpea	Sesame	Sunflower	Mean
Groundnut pod equivalents					
7th May	682	785	1101	190	690
	(758)	(872)	(612)	(316)	(639)
18th May	564	494	517	186	440
	(627)	(549)	(287)	(310)	(443)
27th May	447	320	238	177	295
	(496)	(355)	(132)	(294)	(319)
Mean	564	533	619	184	
	(627)	(592)	(344)	(307)	
	Crops		Dates		Interaction
Sem±	10.2		8.8		17.7
CD (0.05)	22.9		26.0		51.9
Figures in parenthesis indicate actual seed yields of pre-monsoon crops					
Pod yield of groundnut					
7th May	573	657	640	495	591
18th May	463	493	508	323	447
27th May	-	-	501	-	-
Mean	518	575	550	409	-
Total system yield (groundnut pods)					
7th May	1255	1443	1741	685	1281
18th May	1027	983	1025	509	886
27th May	447	320	739	177	421
Mean	910	915	1168	457	
	Crops		Dates		Interaction
Sem±	57.3		49.6		99.3
CD (0.05)	170.0		145.6		291.2

Weather during the crop period was normal and there was no much deviation from the decennial mean. Among the 7th May sown crops green gram and sunflower received a rainfall of 394 mm whereas cowpea and sesamum received 330 mm. The 18th May sown crops received 365 mm of rainfall and the 27th May sown crops received 286 mm of rain. Second and third dates of seeding coincided with relatively low rainfall (95.0 and 17.5 mm respectively) during the vegetative growth period affecting the performance of the crops compared with the earliest seeding which received 108 mm rainfall within 30 days of seeding. Earliest seeding experienced bright sunshine hours. Crops seeded on 18th and 27th May received adequate rainfall during maturity phase, but their performance was not comparable with the earliest seeding mainly because of lesser bright Sunshine hours. Groundnut experienced moisture stress at the critical stages of flowering and pod filling stages (total rainfall 524 mm).

Results and discussion

Performance of pre-monsoon crops

The productivity of all the pre-monsoon crops was decreased with each delay in seeding time (Table 1). Among all the crops tested sunflower was a failure. Poor performance of sunflower crop even during the normal *kharif* and as late *kharif* crop in Alfisols of Tirupati has been reported by Sankaranarayana Rao *et al.*, (1990-91). Based on average of three dates of seeding, sesame yielded significantly higher groundnut pod equivalents (619 kg/ha) followed by green gram (564 kg/ha). It was due to well adaptability of these crops for pre-monsoon sowing.

Among the seeding dates, 7th May seeding was found to be the best for all the crops except sunflower, which did not show significant difference in yield with dates of sowing. Groundnut pod equivalents with the first date of sowing was 690 kg/ha and it was significantly superior to second (440 kg/ha) and third (295 kg/ha) dates of seeding. Interaction of sesame seeded on 7th May resulted in significantly higher groundnut pod equivalents (1101 kg/ha) indicating the optimum seeding time for both the crops (Table 1). Earlier seeding resulted in the highest groundnut pod equivalents because of favourable weather for optimum growth leading to improvement in yield of pre-monsoon crops. Delayed seeding resulted in low yields mainly because of soil moisture stress, especially at early stages leading to stunted growth. Adequate rainfall at the reproductive stage could not compensate for the yield loss due to stress at early stages of the crop as per Appala Naidu and Venkateswarlu (1967).

Performance of *kharif* groundnut and system yield

Highest groundnut pod yield (657 kg/ha) was recorded when seeded on 13th August after the earliest seeded (7th May) pre-monsoon cowpea (Table 1). Groundnut yield even with this date was low due to drought for about 20 days from 8th to 28th October, which coincided with critical stages of pegging and pod development. Groundnut performance in general was poor in Alfisols of Southern Agro-climatic Zone of Andhra Pradesh during *kharif* 1994. Total system yield was highest (1741 kg/ha) with the *earliest seeded sesame followed by kharif groundnut* mainly due to favourable weather factors during their crop period. Pre-monsoon period was ideal for sesame and facilitated early seeding of groundnut in *kharif*. The next best sequence (1443 kg/ha) was cowpea seeded on 7th May followed by *kharif* groundnut seeded on 13th August. Vijay Kumar (1997) also reported the highest groundnut pod equivalents of 2330 kg ha^{-1} with sesame-groundnut cropping system in rainfed Alfisols.

Economics

Net monetary returns were higher (Rs 4189 /ha) with sesame compared to cowpea (Rs 2784/ha) and green gram (Rs 2730/ha) (Table 2) followed by groundnut. Sunflower resulted in net loss of Rs 2095/ha. Early seeding of pre-monsoon crops followed by *kharif* groundnut resulted in higher net monetary returns (Rs 5084/ha) and benefit cost ratio compared to delayed seeding due to favourable weather condition for early seeded crops.

Table 2 Net monetary returns (Rs/ha) and cost : benefit ratio

Crop/Date of seeding	Green gram	Cowpea	Sesame	Sunflower	Mean
7th May	4852 (1.63)	6723 (1.87)	9915 (2.32)	-1153 (0.85)	5084
18th May	2572 (1.33)	2133 (1.27)	2750 (1.36)	-2906 (0.63)	1511 (1.15)
27th May	766 (1.20)	-503 (0.86)	-113 (0.98)	-2234 (0.44)	-521 (0.87)
Mean	2730 (1.39)	2784 (1.33)	4184 (1.55)	-2098 (0.64)	

Pre-monsoon sesame seeded on 7th May followed by *kharif* groundnut resulted in highest net monetary returns (Rs 9915) and benefit-cost ratio (2.32) due to higher yields of both these crops. Sesame as pre-monsoon crop was found ideal before normal *kharif* groundnut. However results need to be confirmed before making valid recommendations.

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Effect of nitrogen and sulphur on yield and oil content of sesame (*Sesamum indicum* L.)

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Abstract

The individual and combined effects of four levels of nitrogen (20,40,60 and 80 kg ha^{-1}) and three levels of sulphur (20,40 and 60 kg ha^{-1}) were studied on growth, yield and oil content of sesame on sandy clay loam soils during *rabi* 1997-98 and 1998-99 at Regional Agricultural Research Station, Tirupati, Andhra Pradesh. Nitrogen at 60 kg ha^{-1} and S at 40 kg ha^{-1} had a profound influence on yield components viz., number of capsules/plant, number of seeds/capsule, test weight, seed and oil yield of sesame. Inverse relationship existed between N levels and oil content.

Key words : Sesame, nitrogen, sulphur, oil content

Introduction

The productivity of sesamum grown after harvest of *kharif* rice is very low. It can be increased through better agronomic manipulations. Fertilizer management, especially of nitrogen and phosphorus is one of the most important agronomic features that affect the crop yields. Of late, sulphur has become an important nutrient. Several workers have documented that oilseed crops respond to sulphur remarkably depending on the soil type (Nageshwar Lal *et al.*, 1995). Sarma and Kakate (1993) reported that sesame crop yielded 25-30% more with the application of 40 kg S ha^{-1} compared to no sulphur. Since the information on requirement of nitrogen and sulphur on sesame is meagre, therefore, the present investigations were carried out.

Materials and methods

A field experiment was conducted at Regional Agricultural Research Station, Tirupati during *rabi* seasons of 1997-98 and 1998-99 on sandy clay loam soils containing 0.26% organic carbon, low in available nitrogen (170 kg ha^{-1}), medium in available phosphorus (36.8 kg P_2O_5 ha^{-1}) and potassium (206 kg K_2O ha^{-1}) having neutral soil pH (7.4). The experiment was laid out in randomized block design with factorial concept involving four levels of nitrogen and three levels of sulphur and replicated thrice (Table 1). Sesame cv. Gowri was sown on 23.1.98 and 13.1.99 after the harvest of *kharif* rice. The spacing adopted was 30 x 10 cm. The gross and net plot sizes were 4.5 x 6.0 m^2 and 4.2 x 5.8 m^2, respectively. N and S were applied as per the treatment through urea and gypsum, respectively. Phosphorus and potash were applied at 20 kg ha^{-1} in the form of diammonium phosphate and muriate of potash, respectively, at sowing. The remaining dose of N was top dressed at 30 days after sowing. The crop received four irrigations (including one pre-sowing irrigation) at critical stages i.e., at flowering, capsule formation and seed filling. Oil content was analysed through Nuclear Magnetic Resonance.

Results and discussion

Nitrogen application significantly increased the plant height, capsules per plant, seeds per capsule and test weight with increasing levels from 20 to 60 kg ha^{-1}, but further raise to 80 kg ha^{-1} had no significant effect (Table1). Better translocation of photosynthates from source to sink reflected in the improvement of above yield components. These results are in consonance with the reports of Chandrakar *et al.*, (1994).

The seed yield increased significantly with increase in the levels of N from 20 to 60 kg ha^{-1} in both the years as well as in the pooled basis. Based on the pooled data, the percentage increase in seed yield with 60 kg N ha^{-1} was 22 and 41 over 40 and 20 kg N ha^{-1}, respectively. The increase in seed yield due to nitrogen was due to its profound effect on growth and development of sesame as was evident from the data on various growth characters. It was further supported by significant and positive relation of plant height (0.953), number of capsules per plant (0.767), number of seeds per capsule (0.862) and test weight (0.665) with seed yield. These results are in agreement with the reports of Rao *et al.* (1990).

Table 1 Yield and Yield attributes of sesame as influenced by nitrogen and sulphur (Pooled data, of 1997-98 and 1998-99)

Treatment	Plant height (cm)	No. of capsules/ plant	No. of seeds/ capsule	Test weight (g)	Seed yield (kg ha^{-1})	Oil (%) (1998)*	Oil yield (kg ha^{-1}) (1998)
Level of N kg ha^{-1}							
20	53.2	25.4	41.9	2.2	276	52.6	136
40	60.4	29.6	47.9	3.5	364	52.6	191
60	65.7	32.8	51.8	3.7	467	51.3	238
80	67.6	33.9	53.9	3.8	490	50.2	245
SEm+	1.37	1.00	0.97	0.17	10.96	0.42	67
CD (0.05)	4.01	2.93	2.85	0.49	32.1	1.23	199
Level of S kg ha^{-1}							
20	60.6	28.1	40.5	2.9	360	51.7	187
40	61.3	32.3	42.5	3.1	402	52.5	205
60	62.5	33.3	43.9	3.2	424	52.8	226
SEm±	1.18	0.86	0.84	0.15	9.49	0.36	58
CD (0.05)	NS	2.51	NS	NS	27.80	NS	170

Sulphur application had significant effect on yield attributing characters and seed yield of sesame upto 40 kg ha^{-1} over 20 kg ha^{-1}, but with further raise in the level of S to 60 kg ha^{-1}, the increase in either of the characters was not significant. Increase in these yield parameters could be ascribed to the overall improvement in plant growth, vigour and production of sufficient photosynthates with S fertilisation. A part of the beneficial effect of S on yield attributes could be due to better availability of N, K and S and their translocation which reflected increased yield attributes of the crop.

An increase in N from 20 to 80 kg ha^{-1}, decreased the oil content by 2.4%. At 80 kg N ha^{-1}, the oil content was 50.2%, whereas, at 20 kg N ha^{-1}, it was 52.6%. This trend was expected that higher availability of nitrogen in the root zone enhanced the concentration in the plant and rapidly the carbohydrates were converted into proteins. Thus, the amount of carbohydrates left to get converted into fat is low. Similar results were also reported by Tiwari and Namdeo (1997).

Application of S up to 40 kg ha^{-1} significantly increased the oil content, however, further increase to 60 kg ha^{-1} had no significant effect (Table 1). Sulphur application might have increased the activity of acetic thiokinase, an important enzyme necessary for conversion of acetyl COA into malonyl COA. Similar increase in oil content with sulphur application in sesame was reported by Chaplot (1990). An appreciable increase in oil yield was noted due to the supply of N up to 80 kg ha^{-1} S up to 40 kg ha^{-1} which was due to increase in seed yield. On light clay loamy soils where rice-sesame cropping system is being followed application of N and S can benefit the crop.

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Effect of aerated hydration-dehydration on dry matter production and yield in sunflower, *Helianthus annuus* L.

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Abstract

Aerated hydration-dehydration treatment upto eight hour in fresh seeds and four hour in aged seeds was significant in increasing the total dry matter production and crop growth rate over control. Fresh seeds were more responsive to the treatment in influencing the yield compared to aged seeds.

Key words: Aerated hydration-dehydration, dry matter production, yield, sunflower.

Introduction

Seeds generally loose vigour and fail to put forth a normal seedling due to physiological deterioration during storage. In hybrid seeds, deterioration starts from fourth month onwards and lowers the viability below certification standards (70%) within 8-10 months after harvest under *semi-arid conditions. Under such circumstances*, maintenance of seed vigour, especially in some oilseed crops like sunflower becomes very difficult.

The seed invigoration treatments developed involved hydration of seeds either from osmotic solutions (Heydecker *et al.*, 1973) or water (Basu *et al.*, 1974). In sunflower, invigoration treatment to 4 or 5 - month-old seeds maintained vigour (Dey and Basu, 1982). Pre-sowing treatments increased seedling length of fresh seeds (Kathiresan *et al.*, 1984), dry matter production (Nagappa, 1983) and seed yields (Dey and Basu, 1982) in carried over seeds of sunflower..

Though, hydration-dehydration improved field performance, it has a limitation of lower availability of oxygen to the seed during soaking. Aerated-hydration is one such alternative to supplement the seed oxygen requirement (Powell *et al.*, 1993). The present endeavour deals the feasibility of aerated hydration - dehydration on field performance of sunflower.

Materials and methods

Seeds of sunflower cv. Morden having germinability of 80 % (fresh seeds) and 40 % (old seeds) were subjected to aerated hydration-dehydration treatment in the Department of *Plant Physiology, College of Agriculture*, Rajendranagar, ANGRAU, during *rabi* (1997). For aerated hydration treatment, seeds were soaked in double their volume of water and aerated from bottom using an aerator supplying air at 1.01/min at 27°C (Powell *et al.*, 1993). Fresh and aged seeds of sunflower were soaked for 0, 4, 8, and 12 hours respectively and dried back to their original weight in shade. The effect of this treatment on dry matter *production (DMP), growth parameters and yield* was evaluated under field conditions following standard methodology described by Watson (1952).

Results and discussion

The total dry matter production increased throughout the crop growth period recording a maximum increase at 45 days *after sowing* (DAS). The dry *matter* production was significantly higher in fresh seeds compared to aged ones. Among the treatments, 8 h and 4 h duration recorded maximum values for dry matter production of fresh and aged seeds, respectively (Table 1). The increase in dry matter production can be attributed to the increase in leaf area index which was maximum at 45 DAS in 8 h (1.19) *and 4 h (1.09) duration treatments of fresh and aged* seeds, respectively.

The treated seed influenced the crop growth rate (CGR), which increased upto 45 DAS and decreased thereafter till harvestable maturity. There was a concomitant effect of LAI and dry matter production on CGR. Among the treatments, 8 h recorded higher CGR of 7.12 and 6.63 g m^{-2} d^{-1} in fresh and aged seeds, respectively compared to that of control (6.69 in fresh seeds and 5.79 g m^{-2} in aged seeds at 45 DAS).

Aerated hydration - dehydration for 4 h significantly increased seed yield (659 kg/ha) compared to control (573 kg/ha); the percentage increase being 9.84. Fresh seeds *recorded maximum seed yield of 742 kg/ha compared to* aged seed 621 kg/ha (Table 2). Aged seeds with low

Table 1 Effect of aerated hydration-dehydration on LAI, total dry matter (gm^{-2}) and crop growth rate ($g\ m^{-2}\ d^{-1}$) in sunflower

Treatments	Days after sowing (DAS)								
	15			45			75		
	LAI	*TDM*	CGR	*LAI*	TDM	CGR	LAI	TDM	CGR
Fresh seed									
0 h	0.02	2.76	0.073	1.11	175.50	6.69	0.440	299.21	1.41
4 h	0.02	2.89	1.109	1.17	179.32	6.82	0.469	309.13	1.48
8 h	0.03	3.53	1.270	1.19	190.36	7.12	0.466	317.42	1.49
12 h	0.23	3.02	1.167	1.18	185.33	7.03	0.469	309.63	1.43
Mean	0.02	3.05	1.156	1.17	182.62	6.92	0.462	308.85	1.46
Aged seed									
0 h	0.01	2.09	0.974	0.98	152.58	5.79	0.352	270.83	1.102
4 h	0.02	2.86	1.158	1.09	178.28	6.43	0.426	296.96	1.316
8 h	0.02	2.78	1.015	1.03	172.98	6.63	0.414	292.04	1.427
12 h	0.02	2.74	0.997	1.01	168.15	6.44	0.256	279.91	1.146
Mean	0.02	2.62	1.036	1.04	168.00	6.33	0.362	284.93	1.248
CD (0.05)									
Fresh seed	0.002	0.136	0.090	0.02	5.58	0.296	0.07	4.19	0.246
Aged seed	0.002	0.193	0.141	0.04	7.89	0.419	0.10	5.93	0.348
Fresh x Aged seed	0.004	0.273	0.199	0.05	11.16	0.593	0.15	8.39	0.492

Table 2 Influence of aerated hydration - dehydration on per cent seed set, *test weight (g), seed yield (kg/ha)* and *oil content (%)* in seeds of sunflower

Treatment	Per cent seed set					Test weight					*Seed yield*					*Oil content*				
	0 h	4 h	8 h	12 h	M	0 h	4 h	8 h	12 h	M	0 h	4 h	8 h	12 h	M	0 h	4 h	8 h	12 h	M
Fresh seed	69.3	70.0	72.6	70.6	70.6	4.8	5.1	5.4	5.1	5.1	638	698	742	715	698	3.33	34.6	34.8	33.5	34.0
Aged seed	58.0	67.0	64.6	62.6	63.0	4.6	5.0	4.9	4.6	4.8	508	621	503	446	519	26.9	32.9	30.0	28.1	29.5
Mean	63.6	68.5	68.6	66.6		4.7	5.1	5.1	4.8		574	659	622	581		30.1	33.8	32.4	30.8	
CD (0.05)																				
Fresh seed			1.68					0.15					22					0.61		
Aged seed			2.37					0.21					31					0.863		
Fresh x Aged			3.36					0.30					44					1.221		

germinability recorded less values for oil content. Aerated hydration-dehydration treatment however, increased the oil content in seeds.

An improvement in the germinability of aged seeds after hydration and dehydration is generally attributed to the increased synthesis of RNA and proteins in the first phase of germination and their involvement in subsequent phases of germination (Savino *et al.*, 1979). From this, improvement in seed vigour can be attributed to the maintenance of membrane integrity by the activation of certain metabolic repair mechanisms during the invigoration treatments. This may also improve the growth of the seedling (Villiers, 1972).

Aerated hydration had its overall effect on growth habit. The beneficial effects were apparent from 8 h and 4 h treatments in fresh and aged seeds, respectively in recording more seed yield was a consequence of more dry *matter production*, *leaf* area index and crop growth rates. Further, the invigoration treatments influenced the seed filling, test weight and thereby increased the seed yield to an extent of 9.84 % over control.

In earlier studies, aerated hydration was reported to increase the rate and uniformity of germination in cauliflower and oilseed rape (Powell *et al.*, 1993). From the results it is evident that aerated hydration for 8 h in fresh seeds and 4 h in aged seeds resulted in improving the quality of sunflower seeds. Therefore, aerated hydration-dehydration can be adopted in situations that require rapid establishment and growth of crop. It may also assist in maintenance of the seed quality identical to F_1 hybrids.

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Pre-harvest sprays of calcium and plant growth regulators (PGRs) on dry matter production and yield in sunflower

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Abstract

Pre-harvest sprays of $CaCl_2$ (0.1, 0.5 and 1.0%), BA (10,20, and 30 *ppm*) and GA_3 (50, 100 and 150 ppm) on capitulum of sunflower cv. Morden were imposed at 60, 70 and 80 days after sowing (DAS). Among the treatments, GA_3 (150 ppm) and BA (30 ppm) significantly increased the LAI and dry matter production compared to control. The pre-harvest sprays of, BA (30 ppm) and $CaCl_2$ (0.5%) increased the capitulum diameter, test weight, yield and oil content.

Key words : Pre-harvest spray, BA, calcium chloride, gibberellic acid, sunflower.

Introduction

Seed production aims to produce high quality seeds. Maintenance of seed quality of oilseeds has become one of the serious problems, as their quality usually declines after four months of harvest under ambient conditions. Since sunflower seeds deteriorate quickly under uncontrolled storage conditions, there is every need to slow down their ageing without affecting seed quality.

Exogenous supply of compounds like calcium and plant growth regulators regulate plant metabolism by meeting its nutritional as well as hormonal requirements. Phytohormonal spray on plants can be one of the successful methods to improve the productivity. Foliar application of PGR's like GA_3, IAA, IBA, at button stage in sunflower increased the plant height and LAI (Kene *et al.*, 1995). Supply of NAA maintained plants healthier with more number of leaves (Pain and Sarkar, 1980), while an increase in its concentration decreased leaf area in sunflower during summer (Pain and Sarkar, 1980). The present study deals with the effect of calcium and PGR's on drymatter production and yield in sunflower.

Materials and methods

The field experiment was conducted following factorial RBD consisting of 10 treatments ($CaCl_2$ @ 0.1%, 0.5%, 1.0%; BA @ 10, 20, 30 ppm; GA_3 @ 50, 100, 150 ppm and control) replicated thrice on sandy loams at College of Agriculture, Rajendranagar during *rabi* 1996-97. The above compounds were sprayed on sunflower (cv. Morden) capitulum at 60, 70 and 80 days after sowing (DAS) along with water spray as control. For retention of compounds, an adjuvant (foaming agent) of 0.1% was added to the spray fluids.

Non-destructive analysis was carried on five plants that were tagged separately in each plot. The samples were used for leaf area measurements and dry weight estimations. Leaf area was measured in a leaf area meter (LI-3100, LICOR Nebraska, USA) and the data were used to calculate LAI. Oil percentage in seeds was determined by using Nuclear Magnetic Resonance (NMR) Spectrophotometer (Hobert *et al.*, 1965).

Results and discussion

It was observed that PGR's and $CaCl_2$ treatments at 60 DAS were more effective in increasing the leaf area index, total plant dry weight, capitulum diameter and yield of sunflower compared to other times of application.

Among the treatments $CaCl_2$ (0.5%) and GA_3 (100 ppm) recorded higher values for LAI, while, $CaCl_2$ (0.5%) and GA_3 (150 ppm) recorded higher values for total drymatter production compared to control. Moreover, it was observed that the capitulum diameter differed significantly with the treatments at physiological maturity, wherein application of these treatments at 60 DAS recorded significantly higher capitulum diameter (Table 2) compared to application at 70 and 80 DAS. Irrespective of the treatments and time, application of BA especially at 20 and 30 ppm was effective in recording higher values for capitulum diameter. $CaCl_2$ at 1% and BA at 20 ppm recorded significant increase in test weight, yield and oil content especially, when they were applied at 60 DAS (Tables 2 and 3).

Table 1 Effect of Pre-harvest sprays of calcium and plant growth regulators on leaf area index and plant dry weight in sunflower

Treatment	Leaf area index (LAI)			Mean	Plant dry weight (g)			Mean
	60 DAS	70 DAS	80 DAS		60 DAS	70 DAS	80 DAS	
$CaCl_2$ 0.1%	0.870	0.807	0.783	0.820	141.59	136.13	134.26	137.33
$CaCl_2$ 0.5%	1.082	0.933	0.837	0.951	159.46	148.72	130.12	146.10
$CaCl_2$ 1.0%	0.870	0.820	0.767	0.819	140.24	134.44	131.82	135.50
BA 10 ppm	1.057	0.803	0.759	0.873	156.50	125.96	121.83	134.76
BA 20 ppm	0.831	0.790	0.749	0.790	131.65	128.50	124.18	128.11
BA 30 ppm	1.057	0.847	0.807	0.903	129.47	124.36	121.34	125.05
GA_3 50 ppm	1.052	0.770	0.731	0.851	126.97	122.96	119.60	123.18
GA_3 100 ppm	1.159	0.857	0.807	0.941	133.19	131.96	127.44	130.86
GA_3 150 ppm	1.037	0.900	0.857	0.931	165.72	143.64	141.64	150.33
Control (water spray)	0.717	0.677	0.647	0.680	132.06	112.34	108.40	117.60
Mean	0.973	0.820	0.774		141.68	130.90	126.06	
	Time of application	Treatments	Interaction		Time of application	Treatments	Interaction	
SEm±	0.007	0.012	0.021		0.42	0.76	1.32	
Cd (0.05)	0.013	0.0249	0.041		0.84	1.53	2.65	

Table 2 Effect of Pre-harvest sprays of calcium and plant growth regulators on diameter of capitulum (cm) and test weight (g) in sunflower

Treatment	Capitulum diameter (cm)			Mean	Test weight (g)			Mean
	60 DAS	70 DAS	80 DAS		60 DAS	70 DAS	80 DAS	
$CaCl_2$ 0.1%	18.17	17.78	17.14	17.68	3.65	3.56	3.41	3.54
$CaCl_2$ 0.5%	19.94	18.80	18.20	19.01	5.12	4.87	4.11	4.71
$CaCl_2$ 1.0%	20.24	19.35	18.72	19.43	5.15	4.58	4.33	4.68
BA 10 ppm	20.02	17.74	16.92	18.23	5.55	4.19	3.96	4.56
BA 20 ppm	21.02	20.40	19.44	20.29	5.02	4.52	4.26	4.60
BA 30 ppm	21.26	20.26	19.09	20.20	3.10	3.04	2.91	3.01
GA_3 50 ppm	19.31	18.94	17.96	18.74	3.77	3.65	3.48	3.63
GA_3 100 ppm	19.45	18.96	18.22	18.87	3.96	3.62	3.45	3.68
GA_3 150 ppm	19.60	19.19	18.50	19.10	3.70	3.33	3.14	3.39
Control (water spray)	17.78	16.89	15.88	16.85	2.90	2.24	2.83	2.65
Mean	*19.68*	*18.82*	*18.02*		*4.19*	3.76	3.59	
	Time of application	Treatments	Interaction		Time of application	Treatments	Interaction	
SEm±	0.10	0.18	0.31		0.03	0.06	0.10	
Cd (0.05)	0.21	0.36	0.63		0.06	0.11	0.20	

Table 3 Effect of Pre-harvest sprays of calcium and plant growth regulators on seed yield per plant (g) and oil content (%) in sunflower

Treatment	Seed yield/plant (g)			Mean	Oil content (%)			Mean
	60 DAS	70 DAS	80 DAS		60 DAS	70 DAS	80 DAS	
$CaCl_2$ 0.1%	34.73	33.61	31.83	33.39	39.14	32.77	33.86	35.25
$CaCl_2$ 0.5%	37.49	33.37	23.05	31.30	37.82	35.08	36.05	36.31
$CaCl_2$ 1.0%	45.23	36.07	33.35	38.21	30.55	34.70	34.47	33.24
BA 10 ppm	46.23	29.56	28.69	34.83	30.44	35.06	38.67	34.72
BA 20 ppm	39.81	33.59	31.20	34.87	41.10	35.84	33.40	36.78
BA 30 ppm	34.16	30.12	27.04	30.44	32.07	30.86	43.81	35.58
GA_3 50 ppm	33.55	31.28	26.87	30.57	35.86	30.81	32.86	33.18
GA_3 100 ppm	36.36	31.79	28.91	32.35	34.27	31.73	37.07	34.36
GA_3 150 ppm	27.31	24.78	21.62	24.57	30.14	35.25	30.53	31.97
Control (water spray)	19.75	15.24	18.00	17.66	24.60	24.56	27.31	25.49
Mean	35.46	29.94	27.05		33.60	32.66	34.80	
	Time of application	Treatments	Interaction		Time of application	Treatments	Interaction	
SEm±	0.1068	0.1951	0.3329		0.31	0.56	0.97	
Cd (0.05)	0.2141	0.3909	0.3771		0.31	1.12	1.94	

The increase in LAI as a consequence of increase in plant height can be attributed to the increase in size of assimilatory surface area of the leaves. Perhaps supply of calcium and growth regulators might have influenced cell elongation and leafiness character.

Some of the previous findings made it clear that application of cytokinins increased the number of leaves by delaying their senescence in safflower (Patil *et al.*, 1980). Similarly, delayed senescence resulted in more number of leaves and increased LAI due to GA_3 in sunflower (Kene *et al.*, 1995).

The pre-harvest sprays with GA_3 followed by $CaCl_2$ and BA at 60 DAS significantly increased the total drymatter production and was attributed to the concomitant effect of the above compounds on the growth of the foliage (LAI) and capitulum diameter. This increase in the size of the capitulum was also attributed to the increase in the number of filled seeds and test weight. The increase in seed number was observed due to application of cytokinins in safflower (Patil *et al.*, 1980), GA_3 in sunflower (Shukla *et al.*, 1987) and BA in soybean (Peterson *et al.*, 1990).

From the present findings, it is obvious that foliar application of $CaCl_2$ or BA or GA_3 would be effective at 60 DAS compared to their effects at 70 or 80 DAS. Such significant effect between treatments and time of application would have regulated in efficient mobilization of nutrients and drymatter for increased test weight and thereby yield in sunflower.

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Integrated nutrient management in *kharif* sesame (*Sesamum indicum* L.)

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Abstract

Studies were carried out between 1993 to 1997 under rainfed conditions at five locations to find out the integrated nutrient management in *Kharif* sesame under different soil types. The response to different treatments having organic manure, inorganic fertilizer and biofertilizer were significant on seed yield at all the locations except at Amreli. The economics of different treatments indicated that seed treatment with *Azospirillum* or PSB inoculam and 100% recommended NPK fertilizer dose resulted in highest net return and IBC ratio at all the locations. Further in combination with FYM @ 5 t/ha on Inceptisol at Tikamgarh, Vertisol at Amreli, Aridisol at Mandore, Castor cake @ 1 t/ha on Vertisol at Jalgaon and neem cake @ 0.25 t/ha at Vridhachalam on Alfisol also resulted in highest net returns.

Key words : Organic manure, inorganic fertilizer, biofertilizer, sesame

Introduction

Sesame is the ancient oilseed crop cultivated in most of the states of India. The average productivity of sesame is only 350 kg/ha which is mainly owing to its cultivation in marginal and submarginal lands having low organic matter and poor soil fertility without any nutrient management under rainfed conditions. Integrated use of organic, inorganic and biofertilizers may sustain productivity by improving soil physical conditions and may reduce the costly inorganic fertilizer needs (Singh *et al.*, 1990). Fertilizer is one of the important component of integrated nutrient management in oilseed crops and 26 to 300% increase in yield in rainfed areas was recorded (Subba Rao, 1994). Besides fertilizers, organic manure and biofertilizers are also responsible for obtaining higher yield and reduce the production cost. In sesame *Azospirillum* seed treatment reduce the N requirement by 50% (Reddy and Sudhakarababu, 1996) and PSB inoculation with FYM in groundnut gave higher yield (Balasubramanian and Palaniappan, 1994). Hence, the present studies were carried out on integrated nutrient management in sesame under rainfed condition on different soil types.

Materials and methods

The studies were carried out under the All India Coordinated Sesame Improvement Project at five locations viz; Tikamgarh (Madhya Pradesh), Amreli (Gujarat), Jalgaon (Maharashtra), Vridhachalam (Tamil Nadu) and Mandore (Rajasthan). The characterization of experimental sites is presented in table 1.

Table 1 Characterisation of experimental sites

Characteristics	Centres				
	Tikamgarh	Amreli	Jalgaon	Vriddhachalam	Mandor
Soil taxonomy	*Inceptisol*	*Vertisol*	*Vertisol*	*Alfisol*	*Aridisol*
Soil texture	Sandy	Clay	Clay	Sandy loam	Sandy loam
pH	7.5	7.8	7.28	7.2	7.2
E.C. (m. mhos)	0.14	0.35	0.23	0.44	0.56
Organic carbon (%)	0.26	0.57	0.62	0.45	0.22
Available N (kg/ha)	129.4	127.0	183.5	210.0	98.0
Available P (kg/ha)	8.7	12.8	8.0	18.5	11.2
Available K (kg/ha)	243.0	524.0	426.0	112.0	390.0

Twenty seven treatments consisting of three organic manure (FYM, Neem/Castor cake and control), three inorganic fertilizer (50% recommended NPK, 100% recommended NPK and a control) and three biofertilizer seed treatment (*Azospirillum*, phosphorus solubilizing bacteria (PSB) and a control) were tested in factorial randomized block design with three replications. The studies were conducted during *Kharif* seasons under rainfed conditions at all the locations. The experiment was conducted for four years at Tikamgarh and Amreli (1993, 95, to 1997), three years at Jalgaon (1995 to 1997) and Vridhachalam (93 to 95) and two years at Mandor (1994 and 96). The crop was sown during last week of June to first fortnight of July. Recommended agronomic practices were followed for raising the crop. Yield data were pooled over years and economics was worked out by estimating the cost incurred and yields obtained from the technology. Incremental yield, gross return, net return and benefit-cost ratio were also worked out to calculate the economics of technology used.

Results and discussion

The effect of organic manure, inorganic fertilizer and bio-fertilizer on pooled seed yield among the treatments were significant at all the locations except biofertilizer at Amreli (Table 2).

Table 2 Effect of Organic manure, inorganic fertilizer and biofertilizer on the yield of sesame (kg/ha) (pooled data of 1993-1997)

Treatment	Tikamgarh	Amreli	Jalgaon	Vridhachalam	Mandor	Mean
A. Organic manure						
Control	245	594	556	456	861	542
FYM @ 5 tonne/ha	402	745	776	507	926	671
Neem/Castor cake	374	722	993	535	926	710
CD (0.05)	31	59	6	1	45	
B. Inorganic fertilizer						
Control	246	583	556	456	808	530
50% Recommended NPK	331	704	776	507	904	644
100% Recommended NPK	445	763	993	535	1000	747
CD (0.05)	31	59	96	21	45	
C. Bio-fertilizer						
Control	316	659	635	470	847	585
Azospirillum	347	705	732	493	959	647
Phosphorus solubilizing Bacteria (PSB)	359	687	958	534	907	689
CD (0.05)	31	NS	96	21	45	

Details of Inorganic fertilizer and organic manure used at various centres

Centre	Recommended dose (kg/ha)			Organic manure
	N	P	K	
Tikamgarh	60	40	20	Neem cake 250 kg/ha
Amreli	50	25	00	Castor cake 1 t/ha
Jalgaon	50	00	00	Castor cake 1 t/ha
Vriddhachalam	25	13	13	Neem cake 250 kg/ha
Mandor	40	20	00	Castor cake 1 t/ha

Organic manure

At Tikamgarh on Inceptisol seed yield (402 kg/ha) was significantly higher with FYM @ 5 tonnes/ha as compared to neemcake @ 250 kg/ha (374 kg/ha) and control (245 kg/ha). Similar trend was also noted at Amreli on Vertisol. At Jalgaon, on Vertisol application of castor cake @ 1 tonne/ha gave significantly higher yield (993 kg/ha), whereas at Vridhachalam on Alfisol neem cake @ 250 kg/ha recorded highest yield (525 kg/ha). However, response to castor cake @ 1 tonne/ha (926 kg/ha) was at par with FYM @ 5 tonne/ha (926 kg/ha). Similar results were reported by Singh *et al.*, 1990 indicating beneficial effect of organic manures on seed yield of sesame.

Table 3 Effect of Organic manure, inorganic fertilizer and biofertilizer on the yield of sesame (kg/ha) (pooled data of 1993-1997)

Treatment	Net returns (Rs/ha) over control						Benefit : cost ratio					
	Tikamgarh	Amreli	Jalgaon	Vriddha-chalam	Mandore	Mean	Tikamgarh	Amreli	Jalgaon	Vriddha-chalam	Mandore	Mean
A. Organic manure												
Control	-	-	-	-	-	-	-	-	-	-	-	-
FYM @ 5 tonne/ha	2640	1960	3400	420	700	1824	3.40	0.96	2.40	0.30	0.66	1.54
Neem/Castor cake	1580	260	6740	580	300	1892	0.58	0.87	2.37	0.42	0.70	0.54
B. Inorganic fertilizer												
Control	-	-	-	-	-	-	-	-	-	-	-	-
50% Recommended NPK	1060	1892	1740	248	1570	1302	0.66	3.22	7.70	0.16	3.48	3.04
100% Recommended NPK	2700	2644	6060	755	3140	3060	1.11	1.95	14.15	0.14	3.48	4.70
C. Bio-fertilizer												
Control	-	-	-	-	-	-	-	-	-	-	-	-
Azospirillum	605	925	325	785	2225	937	39.33	60.66	20.66	51.13	47.3	63.85
Phosphorus solubilizing Bacteria (PSB)	845	605	1205	525	1185	873	55.33	39.33	89.30	34.00	78.0	59.19
Market prices of inputs												
Sesame (Rs/kg)	2.0	20.0	20.0	20.0	20.0							
Nitrogen (Rs/kg)	8.0	8.0	8.0	8.0	8.0							
Phosphorus (Rs/kg)	19.0	19.0	19.0	19.0	19.0							
Potash (Rs/kg)	6.0	6.0	6.0	6.0	6.0							
FYM (Rs/tonne)	120.0	200.0	200.0	200.0	200.0							
Castor cake (Rs/ha)	-	2.0	2.0	-	2.0							
Neem cake (Rs/ha)	4.0	-	-	4.0	-							

Inorganic fertilizer

Application of 100% recommended NPK fertilizer recorded significantly higher yield at Tikamgarh (445 kg/ha), Amreli (763 kg/ha), Jalgaon (993 kg/ha), Vridhachalam (535 kg/ha) and Mandor (1000 kg/ha), than 50% recommended fertilizer and control. Similar trend was also indicated under 50% recommended NPK fertilizer which gave significantly higher yield (331, 704, 776, 507 and 904 kg/ha) as compared to control. Similar findings were also reported by Singh *et al.*, 1990, Subba Rao, 1994 and Mondal *et al.*, 1992.

Biofertilizer

Seed yield was significantly lower under control as compared to seed treatment with *Azospirillum* or PSB inoculation. These treatments recorded significantly higher yield at Tikamgarh (359 kg/ha), Jalgaon (958 kg/ha) and Vridhachalam (534 kg/ha). Whereas at Mandor significantly higher yield (959 kg/ha) was noted under *Azospirillum* which was at par with PSB treatment at Tikamgarh. Similar results were also reported by Arunachalam and Venkatesen, 1984; Subbian and Chamy,

1984. At Amreli, there was no significant response to biofertilizer treatments.

The pooled mean across locations indicated that application of organic manure i.e. neem/castor cake recorded higher yield (710 kg/ha) followed by FYM (671 kg/ha). Whereas among inorganic fertilizers, 100% recommended dose of NPK fertilizer registered maximum yield (747 kg/ha). With regard to biofertilizer, seed treatment with *Azospirillum* and PSB also gave higher yields as compared to control (Table 3).

At Tikamgarh, Amreli and Mandore, Castor cake @ 1 tonne/ha, at Jalgaon neemcake @ 250 kg/ha, at Vridhachalam in combination with FYM @ 5 tonne/ha also recorded highest net return and net ICBR over control (Table 3). Similar results were also reported by Reddy and Sudhakara Babu, 1996; Hegde, 1997.

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Economy in soybean (*Glycine max* L. Merrill.) cultivation through zero tillage and biofertilizers*

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Abstract

Field experiments were conducted on soybean cv. JS-75-46 during *kharif* 1996 and 1997 at Chhindwara to economize soybean cultivation through zero tillage and use of biofertilizers. The growth parameters (plant-height and branches plant^{-1}), yield attributes (pods plant^{-1}, seeds pod^{-1} and seed index) and seed yield of soybean were comparable between adequate (cultivator 1 pass + disc harrow 2 pass + levelling 1 pass) and zero (direct seeding without tilling the land after destroying the germinated weeds with the use of paraquat 1.0 kg ha^{-1}) tillage, but latter helped to stabilize the bulk density of soil and resulted in less weed-infestation than former. Zero tillage needed less expenditure and time for land preparation as compared to adequate tillage and thus, proved more remunerative. Inoculation of *Rhizobium* or PSB cultures each @ 5 g kg^{-1} seeds either alone or in combination of both proved superior than absolute control (no use of plant-nutrition) with regard to productivity and net return of soybean. Application of 100 kg DAP ha^{-1} or 5 t FYM ha^{-1} produced higher grain yield of soybean over biofertilizers, with significant differences in only second year, the latter proved to be economically viable. The positive effect of FYM on soil properties emphasized its importance for sustainability of yields.

Key words : Adequate tillage, zero tillage, bacterial inoculation, soybean, yield, economics

Introduction

Soybean is an important rainy season oilseed crop in Satpura Plateau Zone of Madhya Pradesh. It needs timely sowing in first week of July with the onset of monsoon for its optimum performance. Many a times its sowing is delayed due to heavy and incessant rains restricting the timely and adequate preparation of land. Direct seeding after destroying the germinated weeds with potent herbicides may be a better option for its timely sowing (Dubey *et al.*, 1995). Being an energy rich crop, soybean responds well to a high level of fertilizer management (Singh and Saxena, 1972) which is not affordable by poor subsistence farmers of the region. Long term use of unbalanced inorganic fertilizers for plant-nutrition and repeated tillage to obtain clean seed bed for sowing degrade the soil-health which ultimately reduce the crop yields. Thus, the present study was aimed at evaluation of the low-cost production technology for sustainable optimum productivity of soybean.

Materials and methods

Field experiments were carried out on soybean cv. JS 75-46 during rainy seasons of 1996 and 1997 at research farm Krishi Vigyan Kendra, Chhindwara (M.P.). The soil of the experimental field belonged to Vertisol having low available N (226 kg ha^{-1}) and medium available P_2O_5 (22 kg ha^{-1}) and available K_2O (459 kg ha^{-1}) with pH 7.5. The rainfall was 714 and 1218 mm during 1996 and 1997, respectively. Twelve treatments were tested in randomized block design with four replications (Table 2). Sowing was done on 12.0 m x 4.8 m plots by using 100 kg seeds ha^{-1} in the rows 30 cm apart. FYM was incorporated before final preparation of seed beds under adequate tillage, while it was broadcast before sowing of seeds under zero tillage. The DAP was applied in the rows at the time of sowing below the seeds. Before sowing, firstly seeds were treated with thiram + bavistin (1:1 ratio) @ 3 g kg^{-1} seeds and then seeds were inoculated with different bacterial cultures as per treatments. One hand weeding was done at 30-day growth stage of crop. The crop sown in July 14 and 12

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Table 1 Effect of tillage and biofertilizers on growth, yield attributes and seed yield of soybean

Treatment	Plant height (cm)		Branches plant^{-1}		Pods plant^{-1}		Seeds pod^{-1}		Seed index		Seed yield (q ha^{-1})		
	1996	1997	1996	1997	1996	1997	1996	1997	1996	1997	1996	1997	Mean
Tillage													
Adequate	67 5	55.5	5.0	5.0	34.2	33 2	2 4	2.4	12.7	12 7	16 71	20 32	18.51
Zero	67 7	55.1	4 7	4 8	34.3	34.0	2.4	2 4	12.8	12 7	16 46	20 89	18.67
SEm±	0 20	0 60	0.09	0.06	0 02	0 06	0.01	0.01	0.19	0.16	0.27	0.17	-
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-
Nutrient management													
Control	59.1	45 3	3.3	3 5	25.5	26 7	2.2	2.2	12.3	12.3	12 29	16.95	14.62
100 kg DAP ha^{-1}	69 2	56 3	5.4	5.6	37.6	34 9	2.5	2.5	12.4	12.6	18 04	23 14	20.59
5 t FYM ha^{-1}	69.6	56.5	5.4	5 0	36 3	25 0	2 5	2 5	12.8	12.8	17 65	22 50	20 07
Rhizobium 5 g kg^{-1} seed (a)	69 4	57 5	5 2	4 9	34.7	34 5	2 4	2.4	13.0	12.8	17.25	19.53	18 39
PSB 5 g kg^{-1} seed (b)	69.4	58.4	5.0	4.9	35.1	34 6	2.4	2.4	12.5	12 7	16.90	20 55	18 72
a + b	68.9	58.0	5.5	5.2	36 6	35.9	2.5	2 5	12 9	12.8	17 40	20 96	19 18
SEm±	0 4	0 9	0 2	0 1	0 4	1 0	0 04	0 03	0 15	0.08	0 46	0 30	-
CD (0 05)	1.2	2.6	0.5	0 3	1.2	2 8	0.11	0.09	0.42	0.20	1.34	0.87	-

Table 2 Effect of tillage and biofertilizers on seed yield, economics and soil properties

Treatment	Seed yield (q ha^{-1})			Gross returns * (Rs ha^{-1})	Net returns* (Rs ha^{-1})	Benefit : cost ratio	Soil properties				
	1996	1997	Mean				Bulk density (g cc^{-1})	OC(%)	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})
Initial status							1.35	0.56	17.8	582	7.8
A + Control	12.54	16.91	14.73	14732	7262	1.97	1.33	0.57	14.9	366	6.4
A + 100 kg DAP ha^{-1}	17.46	22.71	20.09	20092	11703	2.39	1.31	0.55	15.3	378	7.6
A + 5 t FYM ha^{-1} seeds (a)	18.18	22.32	20.25	20255	10285	2.03	1.35	0.69	18.0	387	6.3
A + *Rhizobium* 5 g kg^{-1} seeds (a)	17.03	18.92	17.98	17980	10410	2.38	1.33	0.59	15.9	401	6.2
A + PSB 5 g kg^{-1} seeds (b)	17.20	20.44	18.82	18826	11256	2.49	1.32	0.58	14.6	381	6.7
A + (a +b)	17.89	20.60	19.24	19246	11576	2.51	1.33	0.56	15.1	373	7.2
M + Control	12.03	16.99	14.51	14517	8447	2.39	1.35	0.56	14.6	396	6.3
M + 100 kg DAP ha^{-1}	18.63	23.57	21.10	21105	14115	3.02	1.34	0.57	15.0	388	7.8
M + 5 t FYM ha^{-1}	17.12	22.67	19.90	19901	11221	2.32	1.38	0.67	18.3	375	7.1
M + *Rhizobium* 5 g kg^{-1} seeds (a)	17.47	20.13	18.80	18806	12636	3.05	1.35	0.60	15.1	380	6.8
M + PSB 5 g kg^{-1} seeds (b)	17.60	20.66	118.63	18631	122461	3.02	1.36	0.56	15.3	393	6.5
M + (a +b)	16.91	21.32	19.12	19120	12850	3.05	1.35	0.57	14.7	382	7.8
SEm ±	0.66	0.42	-	452	-	-	-	-	-	-	-
CD (0.05)	NS	NS	-	1266	-	-	-	-		-	-

A = Adequate tillage; M = Zero tillage; * Mean of two years was harvested on October 24 and 28 during 1996 and 1997, respectively. Observations on plant height, branches plant^{-1}, pods plant^{-1}, seeds pod^{-1}, seed-index and seed yield were recorded at maturity. The economics of the treatments was determined on the basis of existing market price of inputs and output on mean seed yields under different treatments. The changes in physico-chemical properties of soil after completion of two-year cycle of cropping, over their initial status were assessed.

Results and discussion

Growth and yield

Growth parameters *viz.*, plant-height, branches plant^{-1}, pods plant^{-1}, seeds pod^{-1} and seed index were almost at par under adequate and zero tillage during both years of experimentation (Table 1). Obviously, both the tillage packages were equally favourable for germination of seeds and further growth of plants. Therefore, seed yields of soybean were comparable between adequate and zero tillage. Similar results were reported by Dubey *et al.*, (1995) and Dubey *et al.*, (1996).

The growth (plant-height and branches plant^{-1}) and yield attributing parameters (pods plant^{-1}, seeds pod^{-1} and seed index) were at par due to nutrient management through different sources. But the values were numerically higher with 100 kg DAP ha^{-1} and 5 t FYM ha^{-1} than those obtained with inoculation of *Rhizobium* or PSB alone as well as in combination of both. All the nutrient management levels proved significantly superior to control in these regions. Consequently, application of 100 kg DAP ha^{-1} produced maximum seed yield among all nutrient management levels, but differences were significant only during 1997 with different bacterial inoculations. Through bacterial inoculation with *Rhizobium* or PSB alone as well as their combined application significantly produced lesser seed yields than former treatments, they were significantly superior to control. It appears that application of 5 t FYM ha^{-1} provided plant nutrition as good as that provided by 100 kg DAP ha^{-1}. But bacterial inoculations supplemented partial need of nutrients. These results are in close conformity with the findings of Mehta *et al.*, (1996) and Ramamurthy and Shivashankar (1996).

Economic viability

An additional investment of Rs.1400 ha^{-1} was needed for seed bed preparation under adequate tillage over zero tillage, but seed yield was comparable under both tillage practices (Table 2). Therefore, zero tillage appeared to be more economically viable in terms of net profit and benefit-cost ratio, besides being easy and less time consuming. The cost of DAP was very high as compared to bacterial inoculation, hence bacterial inoculation proved to be more remunerative with regard to benefit-cost ratio, although the former fetched higher net profit. FYM may be costly when purchased from the market mainly due to increased cost of transportation, but it may workout cheaper when prepared on farm. The results are in agreement with the findings of Dubey *et al.*, (1995), Dubey *et al.*, (1996) and Kulkhare *et al.*, (1997).

Soil properties

The bulk density of soil was stable after two years of experimentation under minimum tillage, but it slightly decreased under adequate tillage. Application of FYM helped to safeguard the deterioration of soil aggregates. Soil pH was unchanged due to continuous cropping of soybean for two years under different tillage operations and use of DAP or FYM or biofertilizers. A little enrichment of organic carbon and N contents in soil was noted due to use of FYM for two years. Available P and S contents of soil declined over their initial status after two years of experimentation, when DAP and bacterial cultures were used for plant nutrition. But reduction of P and S was not much when FYM was used. The K status of soil remained stable with the use of different biofertilizers, application of DAP and FYM. Similar results were reported by Wrucke and Arnold (1985) and Saxena and Chandel (1997).

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Effect of irrigation, sowing date and nitrogen on the incidence of painted bug, *Bagrada hilaris* Burm. in mustard

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Abstract

Field experiments were conducted to study the influence of irrigation, date of sowing and nitrogen level on the incidence of painted bug, *Bagrada hilaris* Burm in mustard during *rabi* seasons of 1995-96 and 1996-97 at College Farm, College of Agriculture, Gujarat Agricultural University, Junagadh. Early sown crop (up to 15th October) escaped from the bug infestation, while late sown crop (1st and 15th November) and high dose of nitrogen (75 kg N/ha) increased the population of this pest.

Key words : Mustard, painted bug, irrigation, sowing date, nitrogen

Introduction

Painted bug is one of the serious pests of cruciferous crops. In early crop stage, the nymphs and adults suck the cell sap of leaves causing white blotchy spots, which coalesce and completely devastate the crop, necessitating resowing. However, in latter stage, the pods get curled which have shrivelled grains. Much emphasis had been laid primarily on the chemical control of painted bug, but no work was done on the effect of cultural practices on its incidence and hence the trials were undertaken.

Materials and methods

The field experiment was conducted in a split-split plot design during *rabi* season of 1995-96 and 1996-97 at College Farm, College of Agriculture, Gujarat Agricultural University, Junagadh. The mustard variety Gujarat Mustard - 1 was used for the studies during both the years. The distance between rows was 45 cm and between plants was 15 cm by thinning at 15 days after sowing in each plot. The main plot treatments consisted of two levels of irrigation (5 and 4) at an interval of 15 and 20 days after two common initial irrigations, respectively. The sub-plot treatments consisted of four dates of sowing (1^{st} and 15^{th} October and 1^{st} and 15^{th} November). The sub-sub plot treatments consisted of three levels of nitrogen (25, 50 and 75 kg N/ha). Each treatment was replicated three times with a main plot size of 5.00 x 32.40 m while, the size of sub plot and sub-sub plot was 5.00 x 8.10 m and 5.00 x 2.25 m, respectively.

Ten plants were selected randomly form each net plot to record the absolute population of nymph and adults of painted bug on mustard. The observations were pooled from the trials of two years and conclusions were drawn accordingly.

Results and discussion

Irrigation

The population of painted bug ranged between 0.22 to 1.40 bug(s)/10 plants from 9^{th} to 13^{th} week after sowing (WAS) in both the treatments of irrigation. There was no significant influence of irrigation levels on the occurrence of bug, but the population was comparatively lower on plants which received 4 irrigations (I_2) than those which received 5 irrigations (I_1) (Table 1).

Date of sowing

First October (D_1) and 15^{th} October (D_2) sown crop escaped from the infestation of painted bug (except 12^{th} WAS in October 15^{th} sown crop), whereas late sown crop showed highest bug population of 2.36 and 3.78 bugs/10 plants during 12^{th} WAS in November 1^{st} (D_3) and November 15^{th} (D_4) sown crop, respectively. Joshi *et al.*, (1989) reported that September-October sown mustard had high incidence of pentatomid, however, the infestation was not severe in the crop sown in November-December in Rajasthan.

Table 1 **Effect of irrigation, date of sowing and nitrogen on the incidence of painted bug, *Bagrada hilaris* in mustard (1995-96 and 1996-97 pooled data)**

Treatment	Painted bug population per 10 plants at different weeks after sowing				
	9	10	11	12	13
Irrigation					
5 irrigations (I_1)	0.86 (0.24)*	1.01 (0.52)	1.21 (0.96)	1.38 (1.40)	0.99 (0.48)
4 Irrigations (I_2)	0.85 (0.22)	0.91 (0.33)	1.10 (0.71)	1.24 (1.04)	0.88 (0.27)
SEm ±	0.03	0.03	0.03	0.05	0.03
CD (0.05)	NS	NS	NS	NS	NS
Date of sowing					
1st October (D_1)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
15th October (D_2)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.80 (0.14)	0.71 (0.00)
1st November (D_3)	0.72 (0.02)	0.84 (0.21)	1.35 (1.32)	1.69 (2.36)	0.92 (0.35)
15th Nov. (D_4)	1.26 (1.09)	1.57 (1.96)	1.86 (2.96)	2.07 (3.78)	1.39 (1.43)
SEm ±	0.03	0.04	0.04	0.04	0.04
CD (0.05)	0.09	0.12	0.12	0.13	0.12
Nitrogen					
25 kg N/ha (N_1)	0.08 (0.14)	0.85 (0.22)	1.01 (0.62)	1.16 (0.85)	0.81 (0.16)
50 kg N/ha (N_2)	0.85 (0.22)	0.96 (0.42)	1.18 (0.89)	1.36 (1.35)	0.94 (0.38)
75 kg N/ha (N_3)	0.90 (0.31)	1.06 (0.62)	1.27 (1.11)	1.42 (1.52)	1.04 (0.58)
SEm ±	0.07	0.05	0.04	0.04	0.03
CD (0.05)	NS	0.14	0.13	0.13	0.10

* Figures in parenthesis are retransformed values of $\sqrt{X+0.5}$ transformation

Nitrogen

The population of painted bug was 0.62,1.11, 1.52 and 0.58 bug(s)/10 plants during 10th,11th, 12th and 13th WAS, respectively on the plants which received 75 kg N/ha (N_3). *Significantly the lowest population of the pest (0.16 to 0.85* bug/10 plants) was recorded on plants which received lowest dose of nitrogen (25 kg N/ha). From the results, it could be indicated that the higher dose of nitrogen made the plants more succulent and this crop had higher population of painted bug. Similar results were also obtained by Rawat *et al.*, (1968).

Interaction effect

The interaction effect sowing date x nitrogen was found significant during 11th and 13th WAS. Levels of nitrogenous fertilizer (either 25, 50 or 75 kg N/ha) did not influence the incidence of painted bug during 11th and 13th WAS, when the crop was sown on 1st and 15th October. The lowest population of painted bug was recorded in the crop sown on 1st November (D_3) with nitrogen level of 25 kg N/ha (N_1) during 11th and 13th WAS and it was at par with the treatment combination of D_3N_2 in both the observations. Significantly highest bug population was registered in treatment combination D_4N_3 during 11th (3.93 pentatomids/10 plants) and 13th (2.56 pentatomids/10 plants) WAS and it was either at par (11th WAS) or followed (13th WAS) by treatment combination of D_4N_2 during these periods. Thus, interaction effect indicated that late sowing of mustard with high level of nitrogenous fertilizer favoured the population build up of painted bug.

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Efficacy and economics of application methods of insecticides against safflower aphid, *Uroleucon compositae* Theobald*

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Abstract

Studies conducted to evaluate the effective and economical methods of application of insecticides for the control of *Uroleucon compositae* Theobald on safflower revealed that seed treatment with imidacloprid protected the crop upto 60 days after germination, beyond which the aphid infestation warranted further protection measures. Imidacloprid seed treatment + imidacloprid spray, monocrotophos spray and both imidacloprid and monocrotophos stem applications were effective in controlling the pest. There were no significant differences in percentage population reduction between sprays and stem applications. Sprays with profenofos, imidacloprid, monocrotophos and thiamethoxam recorded higher yield than corresponding stem applications. However, among all application methods, sprays proved to be more effective and economical than seed treatment + sprays and stem applications.

Key words : *Uroleucon compositae*, imidacloprid, efficacy, economics.

Introduction

Safflower is the most promising edible *rabi* oil yielding crop, grown in an area of 6.2 m ha with annual production of 1.49 mt in India (Anon., 1999a).

The crop is attacked by species of insects at various stages of growth, among which aphid, is of greater economic importance (Rai, 1976; Patil and Parlekar, 1987). Yield losses reported due to severe infestation of the aphid ranged from 24 % (Shetgar *et al.*, 1992) to 60 % (Suryawanshi and Pawar, 1980). Spraying and dusting of insecticides have been reported effective for the control of this insect (Satpute *et al.*, 1993; Shetgar *et al.*, 1994; Patel and Shivpuje, 1994). Information on seed treatment and stem application for getting effective and economical control of this pest is lacking and thus, the present investigation was undertaken.

Materials and Methods

Safflower cv. Manjira was sown in second week of November, 1999 in three replications of 10 treatments with a spacing of 45 x 20 cm and raised as per package of recommendations of Directorate of Oilseeds Research, Hyderabad (Anon., 1999b). The plot size was 5 x 5 m. The insecticides viz, imidacloprid (Gaucho 70 WS and Confidor 200 SL) and thiamethoxam (Cruiser 70 WS and Actara 25 WG) as seed treatment + spray, stem application and spray alone profenofos (Curacron 50 EC) as spray and monocrotophos (Nuvacron 36 WSC) as spray and stem application were evaluated for their efficacy against the safflower aphid and the effect of these insecticidal treatments on yield was also investigated. Treated seeds were sown in two treatments (imidacloprid and thiamethoxam). Stem application was done with paint brush on the basal region of the central shoot of the plant at a height of 10 cm from the ground. Subsequent application was done just above this zone. First insecticidal application was given at 60 DAG (days after germination) of the crop and next application followed after three weeks. Population counts were recorded from 5 cm apical twig of five plants selected at random in each plot, one day before and 1,15 days after first and second application of the insecticides. Second application of insecticides was done in four treatments only where the population has crossed ETL (50-70 nymphs and adults/5cm apical twig). The data were subjected to angular transformed values.

Results and discussion

Aphid control

It is evident from the data (Table 1) that seed treatment resulted in delayed as well as low build up of the aphid population when compared to other treatments. Among

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treated plots, imidacloprid plots recorded significant reduction in aphid population, than thiamethoxam at 30 and 60 DAG. Similarly, Mote *et al.*, (1993), Sreelatha and Divakar (1997) reported the efficacy of imidacloprid seed treatment in controlling aphids on cotton and okra.

At 60 DAG (at rosette to flower initiation stage) pest population had crossed the ETL which warranted further protection measures. Ghorpade *et al.* (1993) reported that aphids could be effectively controlled by taking protection measures immediately after branch initiation to first flowering stage of crop growth. One day after first application, it was observed that irrespective of the insecticide applied, sprays registered higher population reduction than stem application (probably due to slower translocation of the insecticides). But 15 DAA (days after application) there was no significant difference between these two application methods. At 21 DAA significant rise in pest population was observed in all thiamethoxam and profenofos sprayed plots. Hence the protection measures were restricted to these four treatments only. Single spray with imidacloprid and monocrotophos maintained statistical parity with two sprays of profenofos. Barbieri and Cavallini (1997) observed that imidacloprid gave excellent control of apple aphids for 75-80 days. Mohite and Moholkar (1988) observed 98% reduction of cabbage aphid by monocrotophos spray and the effect also persisted for longer time. Patil *et al.*, (1997) noticed cent per cent mortality of safflower aphid, after treatment with profenofos.

Yield

Profenofos spray produced the highest yield of 1346 kg/ha (Fig 1) but it was on par with rest of the spray treatments. Stem application with imidacloprid and monocrotophos also registered good yields. However, all thiamethoxam treatments displayed poor performance by recording lower yield compared to other treatments.

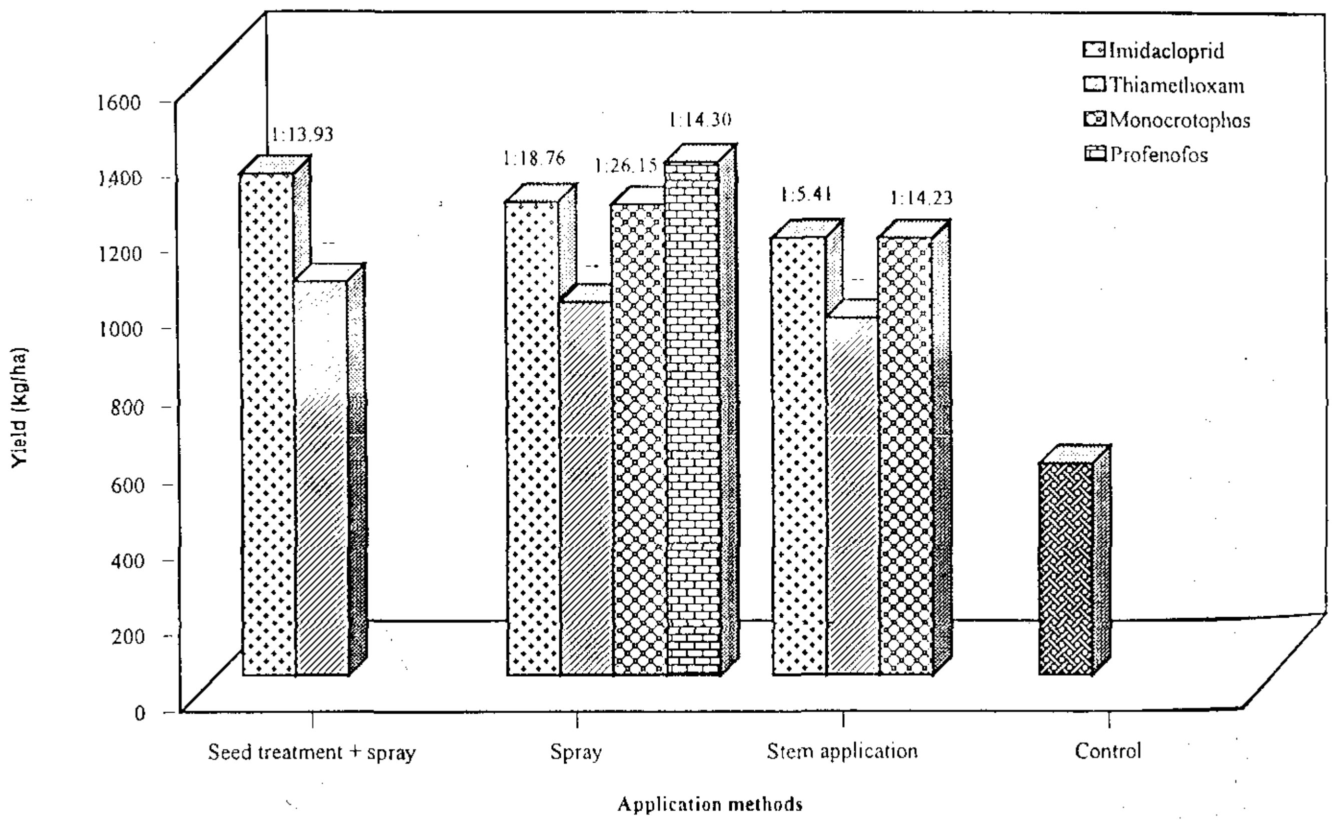

Fig 1 Effect of different insecticidal treatments and application methods on yield of safflower

Table 1 Effect of insecticides and application methods on safflower aphid

Treatment	Concentration	No. of applications	Per cent reduction over control						
			Effect of seed treatment		Effect of sprays and stem application				
					1st application			2nd application	
			30 DAG	60 DAG (pre-treatment count)	1 DAA	15 DAA	21 DAA (pre-treatment count)	1 DAA	15 DAA
Imidacloprid seed treatment + spray	7.5 g ai/kg seed + 100 ml/ha	1	100(90.00)	43.12 (41.04)	88.36 (70.35)	99.17 (86.97)	91.97 (73.83)	94.44 (76.55)	99.70 (88.20)
Imidacloprid spray	100 ml/ha	1	25.00 (29.96)	1.97 (6.90)	87.12 (69.07)	97.57 (81.08)	80.16 (64.16)	89.48 (73.24)	98.69 (84.64)
Imidacloprid stem application	1 : 20	1	34.57 (36.42)	5.40 (12.37)	31.89 (33.55)	95.81(78.22)	93.60 (75.40)	96.55 (79.32)	98.90 (85.16)
Thiamethoxam seed treatment + spray	2.5 g ai/kg seed + 25 g ai/ha	2	78.57 (62.64)	20.11 (26.45)	42.02 (40.24)	44.08 (41.56)	29.65 (32.85)	34.93 (36.17)	45.12 (42.20)
Thiamethoxam spray	25 g ai/ha	2	23.81 (28.83)	10.34 (18.20)	34.27 (34.62)	43.05 (40.18)	31.67 (33.78)	40.74 (39.55)	45.02 (42.11)
Thiamethoxam stem application	1 : 20	2	23.81 (23.83)	3.27 (8.66)	19.93 (25.36)	37.31 (37.38)	18.62 (25.40)	26.86 (31.08)	41.41 (39.99)
Profenofos spray	1 ml/lit	2	33.33 (35.22)	7.54 (15.66)	82.69 (65.77)	90.56 (72.78)	68.13 (55.68)	91.26 (74.75)	100.00 (90.00)
Monocrotophos spray	1.6 ml/lit	1	25.00 (29.69)	4.69 (11.25)	81.84 (65.16)	98.74 (84.82)	95.56 (77.88)	96.58 (79.41)	98.75 (84.89)
Monocrotophos stem application	1 : 4	1	29.76 (32.73)	6.59 (14.62)	65.81 (54.31)	97.24 (80.56)	94.69 (77.24)	97.14 (81.01)	98.99 (84.20)
Control	-	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
SE±			3.800	3.967	4.570	6.366	4.136	5.037	3.055
CD (0.05)			7.984	8.334	9.602	13.375	8.690	10.583	6.420

Figures in parenthesis are angular transformed values; DAG = Days after germination; DAA = Days after application.

Economics

The comparative economics of these application methods revealed that each additional rupee spent for spraying monocrotophos yielded highest returns of Rs. 26.15 and imidacloprid stem application yielded the least return of Rs. 5.41. Thiamethoxam is a new insecticide which is still under preliminary trial stage. Price fixation is not yet done, hence ICBR was not calculated. Further the benefit accrued from sprays was higher than that from stem application and hence it is economical to go in for sprays only.

Though stem application technique is highly effective in controlling the pest, it is not practical for safflower crop due to the spiny nature of the crop and requiring more quantity of pesticide because of high plant density, which in turn involves more labour. On the contrary, stem application in cotton was found to be economical, owing to less plant density. Based on this it can be concluded that, one spray with monocrotophos 1.6 ml/lit is the most economical measure of aphid control.

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Technological constraints in adoption of sesame, *Sesamum indicum* L. production technology in Rajasthan

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Abstract

The present study was undertaken to know the extent of knowledge and adoption of improved package of practices of sesame (*Sesamum indicum* L.) cultivation and probable technological barriers, which affect the adoption of these practices. The data were collected by structured questionnaire from 144 Sesame "growing farmers" of agro climatic zone I-a, II-a, II-b, and V. The existing knowledge and adoption level of Sesamum growers was not up to the mark and there existed a knowledge gap of 76.26 and adoption gap of 65.72 maximum per cent score (MPS). It was also found that farmers faced relatively more constraints in adoption of practices related to plant protection measures, seed treatment and ecological problems (48-55 MPS). Contrary to this, less problems were faced by them in following recommendations with respect to post harvest technology, marketing, method of sowing and seed rate.

Key words : Constraints, adoption, technology, sesame

Introduction

Sesame the oldest oilseed known to man is cultivated throughout the tropical and warm temperate regions of the world for its excellent qualities of seed, oil and meal. India, China, Sudan, Mexico, Turkey, Burma and Pakistan are the important sesame producing countries. India ranks first in the world, both in the area and production of sesame. The annual area under the crop in India is about 2.5 million hectares (45 % of the world "acreage") and the total production is nearly 52 thousand tones.

Rajasthan is the second largest sesame growing states in India after Uttar Pradesh, occupying nearly 40-50 % of the total acreage. The present study was undertaken to find out the extent of knowledge and adoption of improved package of practices of Sesame cultivation by Rajasthan farmers and to identify major constraints being perceived by the Sesame "growers" in adoption of improved cultivation practices.

Materials and methods

Out of the nine agro-climatic zones of Rajasthan, four zones namely Zone I-a, II-a, II-b, and V where Sesame is a major *kharif* oilseed crop were selected for the study. For proper representation, three tehsils, one at NARP head quarters and two extreme ends from NARP head quarters were identified from each zone. Three Village Extension Workers (VEW) circles from each tehsil were selected on the basis of high, medium and low sesame productivity. Thus 36 VEW circles for "growers" were taken for study purpose. Two small and two marginal sesame "growers" from each circle were drawn by Systematic Random Sampling technique making a sum of 144. Data were collected through personal interview technique as per Bhatkar *et al.*, 1966; Verma and Yadav, 1995; Desai and Thakar, 1996. Structured questionnaire was developed in the light of objectives and tested for reliability and validity.

Results and discussion

Knowledge profile

The knowledge profile of the respondents indicated that farmers of all the zones had poor knowledge of improved sesame cultivation practices as the MPS ranged from only 3.92 to 47.29 %. Practice- wise knowledge score highlighted that the farmers possessed average knowledge about sowing time and inter cropping and poor knowledge in other aspects viz., high yielding variety, seed rate, soil treatment, recommended spacing, fertilizer application, weed control, plant protection measures and harvesting and storage of produce. Regarding the irrigation management and seed treatment they have no knowledge (Table 1).

An insight into the knowledge of respondents indicated that majority of them were unaware of improved varieties of sesamum viz., RT-46, RT-125 and TC-25. They were totally unaware of the soil borne insects and control measures against them. Similarly except one or two, none of the respondents knew about the importance and method of seed treatment. It was found that though majority of the respondents knew about the recommended time of sowing i.e. 1st week to mid July, however they could not tell the advantages of timely sowing. Similarly though majority of the farmers knew about recommended seed rate, they were unaware of the seed placement and recommended seed rate apart from the row-to-row and plant-to-plant spacing to be maintained in the field. Less than 20 % growers knew that 45 kg DAP and 30 kg urea/ha should be applied to the crop for best results. Control measures against insect-pest and diseases like capsule borer, blight, powdery mildew, phyllody and leaf spot were not known to majority of the sesame growers. Similarly they were ignorant of the chemical weed control.

Adoption Pattern

Adoption pattern of the sesame farmers indicated that they follow recommendations as regards to time of sowing and seed rate (96.17 and 76.73 MPS). They generally sow the crop from 1st week to mid July depending upon the onset of monsoon, which is as per recommendation (Table 2). Similarly, recommended seed rate of 2.5 kg/ha was followed by most of the farmers. However, regarding improved seed, it was found that farmers generally prefer local seeds as very few were using improved varieties like RT-46, RT-125 and TC-25. Soil and seed treatment measures were adopted by few farmers. Regarding the method of sowing, majority of the respondents of zone I-a and around 40 % of zone of II-a reported that they placed the seed and fertilizer separately during sowing and the depth of the seed is generally kept at 5 cm. The recommendations with respect to spacing in the field were followed by only one fourth of the respondents. It was observed that the respondents in general were applying 15 kg DAP and 10 kg urea/ha which is less than the recommended quantity of 45 kg DAP and around 30 kg urea/ha. Around one third of the farmers expressed that they intercropped sesame with pearl millet/green gram/cluster bean.

Except one or two, none of the farmers were using herbicides and plant protection chemicals for the control of weeds, insect-pests and diseases. Though sesame is purely grown as a rainfed crop, in the absence of adequate and timely rainfall at least one irrigation is required at flowering stage, which is the most critical stage. Due to lack of irrigation facilities most of the farmers were not irrigating the crop. Majority of farmers reported that they generally harvest the crop in the last week of September or 1st week of October, which is as per the package for early maturing varieties. They used to sell the produce just after harvest and keep only small quantity for home consumption as well as for seed purpose. Majority of the farmers use Aluminum phosphate tablets in the produce which is kept for the seed purpose to prevent from insect infestation.

The overall scenario revealed that though sesame cultivators were following recommendations with respect to time of sowing, seed rate, harvesting and storage of produce and to some extent method of sowing. However, the other important practices *viz.*, improved seeds, seed treatment, use of herbicides, recommended dose of fertilizer, plant protection measures etc. were not adopted by majority of the respondents which resulted in poor productivity of the crop.

Technological constraints

Major constraints faced by the farmers were related to the use of plant protection measures, seed treatment, ecological constraints and use of chemical fertilizer which were placed at 1st to 4th rank, respectively. Relatively less constraint was experienced in following the recommendations related to time and method of sowing, seed rate, storage and marketing of produce (Table 3).

Assessment of various constraints in adoption of recommended practices highlight that the main constraints were lack of technical knowledge, high cost of inputs, poor purchasing power of farmers, lack of credit facilities, non-availability of inputs in time and in required quantity (specially improved seed) and abiotic constraint mainly the uncertainty of rainfall. With respect to use of improved seed, around 45 % respondents were of the opinion that the improved seed required more organic manure and fertilizer as compared to the local varieties. Similarly 50 % farmers were not convinced of the advantage of using improved seeds. The farmers further expressed the lack of knowledge about row proportion of sesame with pearl millet/green gram in case of intercropping. More than 50 % growers faced the problem of non-availability of equipment for sowing. Small size of land holding, availability of abundant labour and non-availability of green fodder were the main reasons for non-adoption of chemical method of weed control. Apart from lack of knowledge, non-availability of sprayers and dusters was another factor hindering the adoption of plant protection measurers (61.80 %). The major reason for non-adoption of most of recommended practices was the fear of risk due to uncertainty of rainfall, on account of which farmers were not inclined to spend much in the form of inputs. Lack of storage facilities near villages, transportation facilities, knowledge about regulated market and procurement price and low price just after harvest were the main constraints received by the farmers in marketing of the produce.

Table 1 Extent of knowledge about recommended package of practices of sesame cultivation

Practice	Agro climatic zones									
	I-a		II-a		II-b		V		Pooled	
	MPS	R	MPS	R	MPS	R	MPS	R	MPS	R
High yielding Variety	25.30	7	19.68	7	20.88	7	35.35	3	25.30	6
Intercropping	52.20	1	49.40	1	43.37	2	14.86	8	39.96	2
Soil treatment	11.24	10	14.06	9	14.46	9	17.27	7	14.26	9
Seed treatment	4.42	12	2.41	12	4.41	12	4.42	12	3.92	12
Sowing time	46.99	2	42.17	2	54.62	1	45.38	1	47.29	1
Seed rate & quantity	24.10	8	22.49	6	19.28	8	22.49	6	22.09	8
Recommended spacing	17.27	9	12.45	10	7.22	11	10.04	9	11.75	10
Fertilizer application	34.54	3	17.27	8	27.71	6	40.56	2	30.02	4
Weed control	31.33	4	28.92	3	34.54	3	31.72	4	31.63	3
Irrigation management	6.82	11	8.43	11	10.04	10	5.22	11	7.63	11
Plant protection measures	26.91	5	28.51	4	28.92	5	9.24	10	23.40	7
Harvesting & storage	26.51	6	27.31	5	30.92	4	25.70	5	27.61	5
Overall	25.97		22.75		24.69		21.85		23.74	
F value	36.63**		48.62**		54.19**		33.14**			

MPS = Mean per cent score; R = Rank; ** = Highly significant; n = 144

Table 2 Extent of Adoption of package of practices of sesamum cultivation

Practice	Agro climatic zones									
	I-a		II-a		II-b		V		Pooled	
	MPS	R	MPS	R	MPS	R	MPS	R	MPS	R
Improved seed	25.00	7	26.38	7	36.11	6	38.88	5	28.81	7
Soil treatment	2.77	11.5	4.86	10	11.11	9	2.77	12	5.37	11
Seed treatment	5.55	9	5.55	9	0.00	13.5	0.00	14	2.77	12
Time of sowing	94.44	1	97.22	1	94.44	1	98.61	1	96.17	1
Method of sowing	90.97	3	58.33	5	40.97	5	19.44	9	52.42	4
Recommended spacing	57.63	6	38.88	6	32.63	7	30.55	7	39.92	6
Seed rate	80.55	4	77.77	3	63.88	3	84.72	2	76.73	3
Nitrogenous fertilizer	4.86	10	0.00	12.5	9.02	10	41.66	4	13.88	8
Phosphatic fertilizer	2.77	11.5	0.00	12.5	6.25	11	25.00	8	8.50	10
Intercropping	60.41	5	61.80	4	42.36	4	34.02	6	49.64	5
Use of herbicides	0.00	13.5	0.00	13	0.00	13.5	2.77	12	0.69	14
Critical stage irrigation	6.25	8	16.66	8	16.66	8	13.88	10	13.36	9
Plant protection measures	0.00	13.5	0.00	12.5	2.77	12	2.77	12	1.38	13
Harvesting and storage	93.05	2	88.88	2	91.66	2	76.38	3	87.49	2
Overall	37.44		34.02		31.99		33.67		34.28	
F value	73.88**		50.71**		32.45**		33.32**			

MPS = Mean per cent score; R = Rank; ** = Highly significant; n = 144

Table 3 Extent of technological constraints perceived by the sesame farmers

Practice	Agro climatic zones									
	I-a		II-a		II-b		V		Pooled	
	MPS	R	MPS	R	MPS	R	MPS	R	MPS	R
Improved seed	42.93	6	39.23	5	40.10	8	34.49	7	39.19	6
Soil treatment	43.55	5	33.13	9	44.94	4	31.74	8	38.34	7
Seed treatment	*54.52*	*2*	*51.74*	*2*	*56.99*	*1*	*52.67*	*1*	*53.96*	*2*
Method, sowing time and seed rate	21.08	10	21.20	10	28.61	9	29.77	9	25.17	10
Chemical fertilizers	45.33	4	41.90	3	42.55	7	40.33	5	42.53	4
Chemical control of weeds	36.19	9	36.61	7	43.09	6	48.82	4	41.18	5
Plant protection measures	59.20	1	52.45	1	55.69	2	52.63	2	54.99	1
Ecological constraints	46.01	3	39.93	4	55.40	3	49.45	3	47.70	3
Post-harvest technology	39.07	7	33.36	8	44.63	5	28.42	10	36.37	8
Marketing constraints	37.82	8	36.63	6	28.23	10	37.02	6	34.93	9
Overall	42.57		38.62		44.02		40.53		41.44	
F value	22.88**		19.82**		20.41**		30.83**			

MPS = Mean per cent score; R = Rank; ** = Highly significant; n = 144

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Impact of new technologies on the yield and economics of linseed (*Linum usitatissimum* L.) on the farmers' fields

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Abstract

Frontline demonstrations of linseed (*Linum usitatissimum*) organised on the farmers' fields of Tikamgarh district under Bundelkhand agro-climatic zone of Madhya Pradesh during 1995-96 through 1999-2000 revealed that varieties JLT-26, RLC-6 and J-23-10 yielded 161, 221 and 230 % higher seed yield than local variety with farmer's practices. The productivity of linseed ranged from 7.50 to 18.00 q/ha^{-1} with highest *mean yield of 15.58 q ha^{-1}* under recommended technologies. There was an increase of 137 to 310% in seed yield over local check. The demonstrations gave an additional income of Rs. 7792 to 14057 ha^{-1} and 2.96 to 7.78 incremental benefit : cost ratio.

Key words : Frontline demonstrations, linseed, productivity, technology.

Introduction

Linseed is an important oilseed crop in the country, having immense industrial utility. Linseed ranks third among oilseed crops next to soybean and mustard in Madhya Pradesh. It is being grown throughout the state, mostly on marginal and sub-marginal lands under unirrigated and *utera* conditions. The productivity of linseed in the state is low (325 kg ha^{-1}) due to non-adoption of improved technologies i.e., suitable high yielding varieties, proper method of sowing, recommended balanced fertilizers, weed control, plant protection measures and irrigation. Das *et al.*, (1998); Singh and Verma (1998) reported that the yield of linseed can be enhanced by 97-145% with adoption of recommended package of practices. Therefore, it was decided to demonstrate the improved linseed technologies to farmers in the Bundelkhand zone of Madhya Pradesh under front line demonstration programme.

Materials and methods

A total of 92 frontline demonstrations were conducted on farmers' fields in Tikamgarh district of Bundelkhand agroclimatic zone of Madhya Pradesh in sandy loam to clay soils during *rabi* 1995-96 through 1999-2000. The plot size ranged between 0.4 to 1.0 ha. Local practices included sowing seed by broadcast method, use of local variety and application of 50 kg DAP ha^{-1}. The recommended package of practices in demonstration plot included linseed varieties J-23-10, RLC-6 and JLT-26 (pre release) were sown in rows at 25cm apart with a seed rate of 25 kg ha^{-1}. The recommended dose of nutrients included N, P_2O_5 and K_2O at 60, 30 and 20 kg ha^{-1}, respectively. Half dose of nitrogen (urea), full dose of phosphorus (single super phosphate) and potash (muriate of potash) was drilled two days before sowing at a depth of 6 cm and the remaining 50% nitrogen was top dressed at the time of first irrigation. Seeds were treated with thirum at 3 g kg^{-1} seed. Linseed was sown between 20 Oct. to 5 Nov., and harvested between 13-18 March. Hand weeding was done once 25-30 days after sowing. Two sprays of phosphomidon (85 SL) at 0.5 *ml lit*$^{-1}$ of water were given to control bud fly. Fields were irrigated prior to sowing at pre-flowering and grain filling stages.

Results and discussion

Varieties

Among linseed varieties (Table-1) pre-released variety JLT-26 gave the highest (15.05 q ha^{-1}) yield. The next best was RLC-6 (12.55 q ha^{-1}) followed by J-23-10 (11.55 q ha^{-1}). Varieties JLT-26, RLC-6 AND J-23-10 recorded 161,221 and 230%, respectively higher grain yield under recommended package of practices over local varieties with farmers' practices. Malik (1999) also reported that varieties Kiran (RLC-6) and J-23-10 gave 108 and 91%, respectively higher yield compared to local variety at Kanpur. The results are in agreement with those reported by Khare *et al.*, (1999).

Table 1 Performance of improved linseed varieties against local varieties on farmers fields

Variety	Yield ($q\ ha^{-1}$)		Yield of local checks ($q\ ha^{-1}$)	Per cent increase in yield over local check
	Highest	Average		
J-23-10	13.95	11.50	3.50	230
RLC-6	15.26	12.55	7.90	221
JLT-26	15.60	15.05	5.75	161

Grain yield

The productivity of linseed ranged from 7.5 to 18.00 q ha^{-1} with highest mean yield 15.58 q ha^{-1} under recommended improved production and protection technologies. The data indicated that (Table 2) grain yield of 12.30, 10.50, 15.58, 12.45 and 11.62 q ha^{-1} could be obtained with improved technology as compared to 3.00, 3.12, 4.25, 4.71, and 4.30q ha^{-1} with local practices in respectives years. In comparison to local practices, there was an increase of 310, 236, 266, 164 and 137 % in productivity from the demonstration plots during 1995-96, 1996-97, 1997-98, 1998-99 and 1999-2000, respectively. The higher yield of linseed could be attributed to adoption of high yielding varieties, line sowing with 25 cm row spacing, weed control, fertilizer management and plant protection measures. These results are supported by Das *et al.*, (1998) and Singh and Verma (1998).

Income

The economic analysis made on the basis of prevailing market rates (Table-3) showed that the demonstrations gave higher net return of Rs. 9735, 9194, 17112, 14242, and 12141 ha^{-1} compared to Rs.865, 1356, 3055, 4449 and 4349 ha^{-1} under local practices in the corresponding seasons. There was an additional income of Rs.8870 in 1995-96, 7838 in 1996-97, 14057 in 1997-98, 9793 in 1998-99 and 7792 ha^{-1} in 1999-2000 with respective incremental benefit cost ratio of 4.86, 4.21, 7.78, 3.76 and 2.96.

Table 2 Yield of linseed as affected by improved and local management practices on farmers' field

Year	Farmers (No.)	Yield ($q\ ha^{-1}$)				Increase in yield over local check (%)
		Highest	Lowest	Average	Local check	
1995-96	20	14.00	10.50	12.30	3.00	310
1996-97	25	14.50	7.50	10.50	3.12	236
1997-98	12	18.00	13.00	15.58	4.25	266
1998-99	10	14.26	10.96	12.45	4.71	164
1999-2000	25	16.25	8.00	11.62	4.90	137
Mean	-	15.40	9.99	12.49	3.99	213

Table 3 Cost of cultivation, net return and B : C ratio under improved and local management practices

Year	Cost of cultivation (Rs. ha^{-1})		Net return (Rs ha^{-1})		Additional cost of cultivation (Rs ha^{-1})	Additional net returns (Rs ha^{-1})	Incrementa l benefit : cost ratio
	Demonstrations	Local check	Demonstrations	Local check			
1995-96	4410	2585	9735	865	1825	8870	4.86
1996-97	4560	2700	9194	1356	1860	7838	4.21
1997-98	4700	2895	17112	3055	1805	14057	7.78
1998-99	5700	3150	14242	4449	2600	9793	3.76
1999-2000	5880	3250	12141	4349	2630	7792	2.96

The results of frontline demonstrations of linseed have clearly showed that growing of linseed varieties J-23-10, RLC-6 under improved management practices including proper seed rate, line sowing with 25 cm row spacing, weed control, recommended fertilizer, plant protection measures and irrigation proved more productive and remunerative than that grown with traditional practices.

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Short communication

Diversity and collection of niger, *Guizotia abyssinica* Linn. f. Cass germplasm from peninsular India

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Niger is one of the most important minor oil seed crops. India is the largest producer in the world with an annual production of over 0.6 lakh metric tonnes. It is mainly grown in the states of Orissa, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Bihar. The tribal people on hill slopes follow *podu* (shifting cultivation) and grow it due to its low input requirements, adaptability, tolerance to different biotic and abiotic stresses, early maturity and assured yield.

Niger has good import potential and also plays a significant role in the tribal economy and nutrition. In order to collect, conserve and exploit the available niger diversity from important pockets in the peninsular region, a survey was undertaken in parts of Andhra Pradesh, Orissa and Madhya Pradesh during November, 1997.

The explored area had been sub-humid and sub-tropical in nature. The average annual rainfall varied from 1000-1400 mm with the average annual temperature varying from 5^{o}-37^{o}C. The altitude of the collected area ranged from about 600 - 1,000 metres above the MSL. The soil types frequently encountered were black and red. The range of soil types included red loams, red sandy loams, red soil with clay base etc.

It has been observed that, all the niger area is under rainfed conditions. The farmers in all the areas surveyed do not follow the agronomic practices and plant protection measures. Niger is generally grown as a sole crop confined to marginal and submarginal lands on the eroded hill slopes and undulated areas. In limited areas inside the tribal belt niger is grown as a mixed crop/border crop and in some regions as a minor intercrop also.

Apart from niger, the important crop under cultivation in the surveyed area has paddy wherever irrigation sources were available. The other crops which were seen widely growing were sorghum, finger millet, cowpea, pigeon pea, horse gram, tomato, brinjal, chillies, elephant foot yam, bottle gourd, onion, turmeric and ginger etc. Sorghum was seen growing as a sole crop or as an inter-crop with pigeon pea. Finger millet was cultivated as a sole crop in the sandy loams and red soils. *Podu* cultivation was prevalent in many tribal pockets in the districts of Visakhapatnam (Andhra Pradesh), Koraput (Orissa) and Bastar (Madhya Pradesh).

An itinerary was prepared for the collection of niger germplasm in consultation with the research institutes located in the region, State Departments of Agriculture of Andhra Pradesh, Madhya Pradesh and Orissa. The areas surveyed for the collection of niger germplasm are given in Fig.1.

The farmer's field was taken as a unit area and random samples from the population and biased samples of the elite material were collected. Germplasm samples were also collected from the tribal shandies, threshing yards and farm stores. The required scientific and other equipments and general logistics were taken care of as suggested by Marshall and Brown (1975); Engels *et al.* (1995). Each niger germplasm sample was given a collection number and passport and ethnobotanical information was also recorded. The details of the niger germplasm collected are presented in table-1. Two hundred and six accessions of niger germplasm were collected from 82 sampling sites in parts of the districts of Visakhapatnam in Andhra Pradesh, Koraput in Orissa and Bastar in Madhya Pradesh. Niger is known by different vernacular names as *Adusulu, Alusulu, Gaddinoogulu, Verrynoogulu* in Andhra Pradesh, *Alasi, Olisi* in Orissa and *Ramtil* in Madhya Pradesh.

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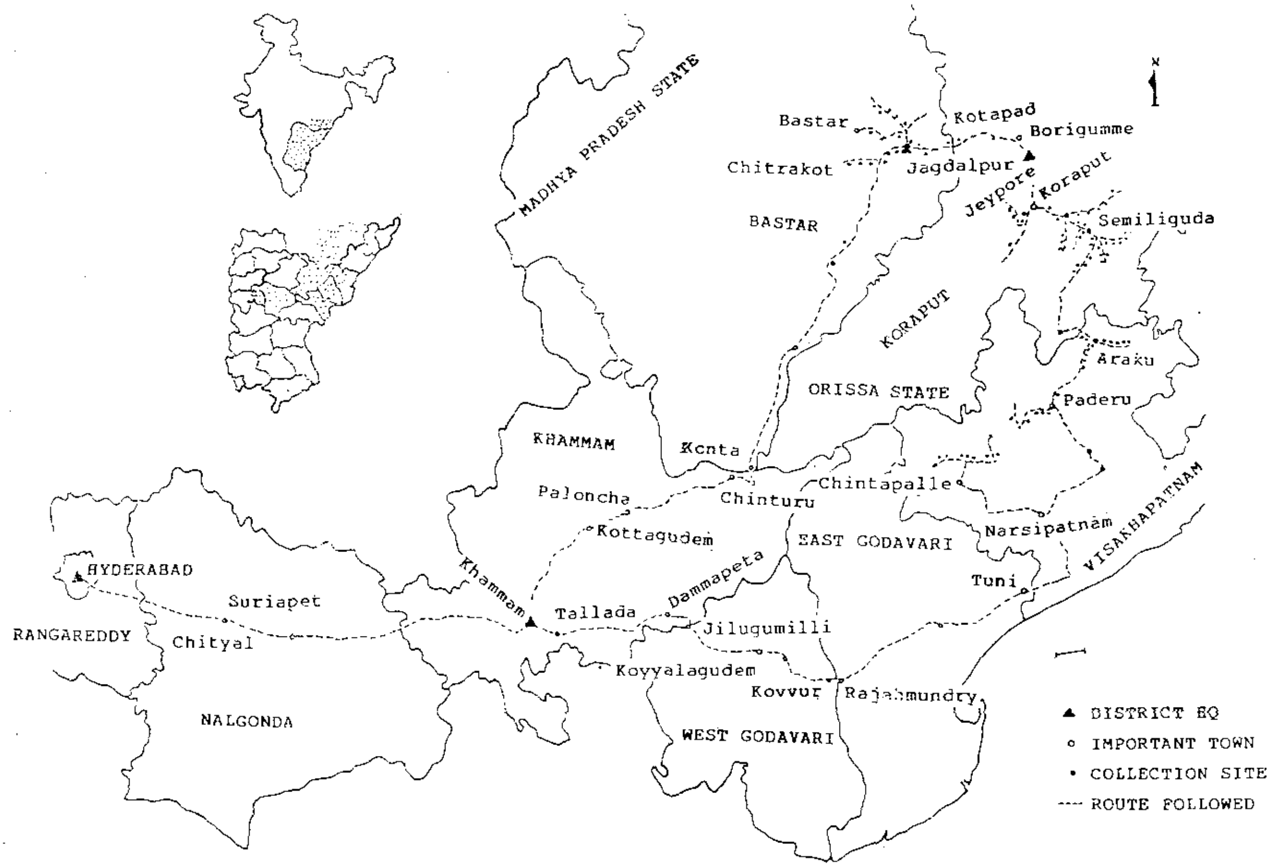

Fig 1 Route map showing the areas surveyed for the collection of niger germplasm from parts of Viskahapatnam (AP), Koraput (Orissa) and Bastar (MP) districts

Table 1 Areas surveyed in the peninsular India for the collection of niger germplasm

State	District	No. of villages surveyed	Total diversity collected
A.P.	Visakhapatnam	37	130
M.P.	Bastar	22	27
Orissa	Koraput	23	49
	Total	82	206

Broad variability was observed in the niger germplasm collected for several phenotypic characters which included, plant height (23-175 cm), number of branches (1-7) and capitula/plant (3-48). The diversity for seed length, 1000-seed weight and oil content are given in table-2. The productivity of niger crop in the surveyed area, as stated by farmers was very low ranging from 70-205 kg/ha. Interesting niger landraces were collected for compact branching, profuse branching, earliness, high yield and high oil content (>42%) during the survey (Table-3). IC-211056 collected from Padmapur village, Koraput block in Orissa recorded the highest oil content of 44.5% which is higher than the available germplasm and improved varieties (37-40%).

Table 2 Range of diversity in seed characters and oil content in the niger germplasm

Character	Range	Mean	SD	CV(%)
Seed length (mm)	3.7-4.8	4.2	0.19	4.5
1000-seed weight (g)	1.3-5.0	3.5	0.72	20.6
Oil content (%)	35.5-44.5	41.3	1.3	5.2

Table 3 Promising accessions of niger germplasm collected during the survey

Character	Accession number
Earliness (< 100 days)	IC-211115
High yield (> 800 kg/ha)	IC-211085, IC-211072, IC-210947, IC-211024, IC-211003
Profuse branching (> 9 branches)	IC-210947, IC-210950
Compact branching	IC-210935
High oil content (> 42%)	IC-211056, IC-210983, IC-210986, IIC-210995, IC-211000, IC-211011, IC-211055

Table 4 Ethnobotanical information collected from tribal groups in the surveyed areas

Tribe/Group	Habitat (District)	Ethnobotanical information
Konda dora	Chintapalli (Visakhapatnam)	Niger oil mixed with castor oil for relief from headache/pain
Proja	Tollamania (Korput)	Used as a medicine oil for massage for relief from body pains
Bhumia	Tondaguda (Koraput)	Seed used as bird feed and cake as a cattle feed. Oil as hair oil/application to wounds/bruises
Valmiki	Panasalapadu (Visakhapatnam)	Oil cake as a cattle feed. Niger oil mixed with sesame oil used as hair oil
Nooka dora	Beesupuram (Visakhapatnam)	Bird feed
Kotiya	Adapavalasa (Visakhapatnam)	Niger oil mixed with castor oil used as hair oil

Some ethno-botanical information on usage of niger was also recorded from Bhumia, Dombu, Goud, Kondadora and Valmiki tribal groups (Table-4). The germplasm collected has been shared with All India Coordinated Research Project on Oilseeds, Jabalpur, Madhya Pradesh and also conserved in the National Gene Bank, NBPGR, New Delhi.

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Short communication

Line x Tester analysis in niger (Guizotia abyssinica Cass)

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The line x tester analysis technique has been extensively used in almost all major field crops to estimate *gca* and sca variances and effects and to understand the nature of gene action involved in the expression of yield and yield attributes. However, the genetic improvement work in a minor oilseed crop like Niger is neglected and there is tremendous scope for its improvement. In view of this, the present work of Line x Tester analysis was undertaken for genetic improvement of niger.

The experimental material comprised three lines, four testers and their 12 crosses. These crosses along with parents were evaluated in randomised block design with two replications at Zonal Agriculture Research Station, Igatpuri during *Kharif*1998-99 under rainfed condition. Each genotype was grown in a single row of five meter length with a 30 x 10 cm spacing. Data were recorded on ten randomly selected competitive plants from each genotype in each replication for days to flower, days to maturity, branches/plant, capsules/plant and seed yield/plant (g). The data so recorded were subjected to Line x Tester analysis of combining ability vide Kempthorne, (1957).

Analysis of variance for combining ability revealed that mean sum of squares due to females (Line), males (Tester), female x male interaction, hybrids and hybrid x parent interaction were highly significant for all traits studied. High magnitude of mean sum of squares due to lines, testers and line x tester interaction indicated the presence of considerable amount of variability among parents and it was manifested in crosses also. The mean sum of squares due to hybrid x parent was significant for yield and yield components, which indicated the presence of heterosis for these characters. The variance due to line, tester, line x tester were highly significant for all traits.

Table 1 ANOVA for combining ability in niger

Source		Mean sum of square				
	df	Days to flower	Days to maturity	Branches/plant	Capsules/plant	Seed yield/plant (g)
Replication	1	0.422	0.440	0.026	0.025	0.031
Female (Line)	2	4.666*	4.670*	0.167	1.167	0.066
Male (Tester	3	33.330**	33.83**	1.458	93.45*	0.057*
Female x Male	6	97.52**	1.27*	2.148*	10.000*	0.154*
Hybrids	11	89.45**	1.28*	6.530*	64.580**	0.483*
Hybrid x Parent	1	3.49**	3.87	11.30*	70.090**	1.594*
Error	18	3.53	1.75	0.74	1.19	0.004
-Female		38.00**	31.50	1.791	28.166*	0.021*
-Male		21.33**	34.83*	10.38*	89.263*	0.415*
-Female x Male		1.406*	2.08*	6.180*	64.369*	0.671*
-*gca*		0.643	0.597	0.028	1.662	0.008
-*sca*		13.800	62.520	0.699	4.403	0.075
gca/sca		0.046	0.009	0.039	0.377	0.108

*,**Significant at five % and one % level, respectively.

However, the magnitude of variance due to tester was higher than due to lines and line x tester interaction. The lower magnificent for all characters, suggested greater uniformity among the hybrids than among the parents. The variance due to *sca* was found to be higher in magnitude than the *gca* for all characters, suggesting preponderance of nonadditive gene action, hold promise for exploitation of heterosis in Niger. These results are in agreement with the finding of Govinda Raju *et al.* (1992) for days to flower, days to maturity, number of filled achenes/capitulum and achene yield/plant in sunflowers. Upadhyay and Reddy (1997) have also observed higher magnitude of *sca* variance for seed yield/plant, 1000 seed weight, days to maturity, plant height, number of branches/plant and number of capsules/plant.

The estimates of *gca* effects for all parents and crosses are furnished in (Table 2). It revealed that the parental lines JN-124 and IGP-76 were good general combiners for seed yield/plant. Besides, IGP-76 was good general combiner for branches/plant and capsules/plant. Early flowering and early maturity with significant negative *gca* effects are desirable. Accordingly, the genotype IGP-76 was found to be a good general combiner for days to flower and days to maturity. Out of 12 cross combinations, five cross combinations for seed yield/plant; three combinations for branches/plant and five combinations for capsules/plant have shown significant positive *sca* effects. The crosses JN-124 x BNS-5, GMS-2 xun-4 and JN-124 x No-71 for seed yield/plant; JN-124 x IGP-76 for branches/plant; JN-124 x IGP-76 for capsules/plant have shown significant and high *sca* effects. It was observed that the crosses which showed highest positive *sca* effects had one parent with high *gca* effect and other with low *gca* effect i.e., high x low or low x high combinations. Intermating between these crosses may be very useful to have more branches and capsules/plant, with high seed yield/plant. This method of breeding will provide opportunity for breaking undesirable linkages if any and will help to produce board base of genetic background for selection. The cross JN-124 x IGP-76 has shown highly significant positive *sca* effects with both the parents possessing high *gca* effects i.e., high x high combination. Such combination is desirable as both additive and nonadditive gene actions can be capitalized. A major part of such variance is fixable in later generations.

Table 2 Estimates of combining ability effects in Niger

Cross	Days to flower	Days to maturity	Branches/plant	Capsules/plant	Yield/plant(g)
GMS-1xIGP-76	-4.167*	13.583**	0.292	1.917*	-0.26*
GMS-1 x UN-4	-4.160*	-3.417*	-0.042	1.583*	-0.06
GMS-1 x No.71	5.83**	-3.417*	1.292*	2.917*	0.61**
GMS-1 x BNS-5	-4.50*	-6.750*	-0.542	-6.417*	-0.28*
GMS-2 x IGP-76	2.83*	3.833*	0.042	2.583*	0.11*
GMS-2 x UN-4	6.83*	7.833*	1.208*	-0.583	0.53**
GMS-2 x No.71	-7.16*	-6.617*	0.042	0.917	-0.18
GMS-2 x BNS-5	-2.50*	-5.500*	-1.292*	-2.917*	-0.45*
JN-124 x IGP-76	1.33	12.250**	2.833*	9.333**	0.45*
JN-124 x UN-4	-2.67*	-4.417*	-1.167	-4.167*	-0.16*
JN-124 x NO.71	-5.67*	-7.417*	-1.333*	-3.833*	-0.42*
JN-124 x BNS-5	-7.00**	-0.417	-0.333	-1.333	0.74**
SEm±	0.99	0.95	0.60	0.75	0.044
Female					
GMS-1	-1.50	-2.250*	0.208	-1.083*	-0.015
GMS-2	2.50*	1.5000*	-0.542	-1.083*	-0.043
JN-124	-1.00	0.750	0.333	2.167*	0.057*
SEm±	0.49	0.47	0.30	0.37	0.22
Male					
IGP-76	-2.66*	-2.25*	1.917*	5.542*	0.364*
UN-4	1.33*	0.167	-1.083*	-2.458*	-0.106
No.71	1.30	2.083*	-0.417	-2.792*	-0.006
BNS-5	0.00	0.917*	-0.417	-0.292	-0.253*
SEm±	0.57	0.55	0.34	0.43	0.025

*, ** Significant at five % and one % level, respectively.

In certain crosses, both the parents have shown their poor gca effects. In such crosses, very little gain is expected, because high *sca* effects are due to nonadditive component of variance, which may not be exploited through simple breeding techniques. In the present study such situation was observed in cross GMS-1 x No-71 for seed yield/plant.

Early flowering and early maturity with high yielding ability are desirable traits in improvement of any crop. In the present study the genotypes IGP-76 and GMS-1 have shown high significant negative *gca* effects for days to flowering and days to maturity. The cross combination JN-124 x BNS-5 and GMS-2 x No.71 for days to flower and JN-124 x No.71 and GMS-1 x BNS-5 for days to maturity have shown significant *sca* effects in negative direction. Intermating between these crosses followed by recurrent selection may give fruitful results in niger improvement with earliness for flowering and maturity.

It was observed that the crosses with high *sca* for seed yield/plant and also average to high sca for component characters, suggesting that the improvement in yield could be obtained by improving its components characters by resorting to more efficient breeding methodologies such as recurrent selection, biparental mating and selective diallel mating methods rather than conventional methods.

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Short communication

Stability for seed yield in F_1 hybrids of sesame, *Sesamum indicum* (L.)

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In India sesame yields are very low because of its cultivation on marginal lands with poor management. Commercial cultivation of hybrid sesame can increase and stabilize the yield of sesame(Barwale and Panchabhaye, 1994). Sesame hybrid have distinct advantages due to low seed rate, high seed multiplication ratio, epipetalous condition for easy emasculation, pollination and also presence of high and exploitable heterosis. The commercial hybrid seed production by hand was reported by many workers and the cost of one kg of seed worked out as Rs. 150-200/- (Manivannan and Ganesan, 1993), Rs. *350-400/- (Thangavelu, 1994) and Rs 1218/-* (Baviskar, 1994). In heterosis breeding, information on stability of hybrids is important. Hence an attempt was made to identify stable F_1 hybrids in sesame.

Ten hybrids of sesame (Table 2) were chosen from the previous line X tester study. These ten F_1 hybrids and one check variety (CO 1) were evaluated during *kharif*, 1993, *summer*, 1994 and *kharif*, 1994 at Faculty of Agriculture, Annamalai University, Annamalainagar. One hundred capsules were crossed for each cross combination to produce sufficient seeds of F_1s during *summer*, 1993, *kharif*, 1993, summer, 1994 seasons. The trial was conducted in a randomised block design with two replications in each environment. Each genotype was sown in plot of 12 m^2 at 30 x 30 cm spacing. Recommended cultural practices were followed. The data on seed yield were analysed for stability parameters using the model suggested by Eberhart and Russel (1966).

Analysis of variance of stability for seed yield (Table 1) showed that Genotype x environment interaction was significant when tested against pooled error which satisfied the requirement of stability analysis. The two components of Genotype x Environment interaction, i.e., Genotype x environment (linear) and pooled deviation were significant when tested against pooled error, which indicated significant differences among the genotypes for both linear and nonlinear responses to different environments. The higher magnitude of genotype x environment (linear) interaction than the pooled deviation revealed the preponderance of linear component for seed yield. It indicates that the performance of genotypes for seed yield could be predicted.

According to Eberhart and Russel (1966), an ideal variety is the one which has high mean performance, average responsiveness (b=1) and high stability (S^2d=o). Among the entries studied, only one hybrid (SVPR 1 x CO 1) recorded significant value of S^2d indicating that the performance of this hybrid for a given environment can not be predicted (Table 2). The hybrid IS 207 x SVPR-1 recorded the regression coefficient of -1.05, which is significantly different from unity and other hybrids had regression coefficients equal to unity. Hence, the hybrid IS 207 x SVPR 1 recorded above average responsiveness to environment and all other entries recorded average responsiveness to environmental variation. Five hybrids namely Thiruvellore local x SVPR 1 (1804 kg/ha), SVPR 1 x CO 1 (1604 kg/ha), RJS 2 x SVPR 1 (1160 kg/ha), BS 6-1-1 x SVPR 1 (1099 kg/ha), and Paiyur 1 x SVPR 1 (1063 kg/ha) recorded significantly higher seed yield than the variety CO 1 (509 kg/ha).

Table 1 Analysis of variance for seed yield in sesame

Source	df	Mean squares
Genotypes (G)	10	19.59**
Environment (E)	2	53.96**
Environment + G x E	22	23.36**
G x E (linear)	10	34.62**++
Pooled deviation	11	5.44**
Error (pooled)	30	1.77
Total	65	

** Significant against pooled error (P=0.01).

++ Significant against pooled deviation (P=0.01).

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While considering mean, responsiveness to environment and stability over environments, all the above mentioned hybrids were more promising. Hence, these stable hybrids can be recommended for large scale cultivation.

Table 2 Stability parameters for seed yield in sesame

Genotypes	Seed yield (kg/ha)	b	s^2d
SI 861 x SVPR 1	991	-1.00	0.46
SI 2257 x SVPR 1	1027	-0.36	5.91
SI 207 x SVPR 1	1045	-1.05#	0.04
IS 305 x SVPR 1	958	0.78	0.68
RJS 2 x SVPR 1	1160	1.87	4.82
BS 6-1-1 x SVPR 1	1099	0.01	0.06
SVPR 1 x CO 1	1604	4.45	37.53**
PAIYUR 1 x SVPR 1	1063	1.92	5.32
GENE 9101 x SVPR 1	964	0.44	3.76
Thiruvellore local x SVPR 1	1804	4.04	0.96
CO 1	509	-0.10	0.31
General mean	917	-	-
SE	190	0.78	-
CD (0.05)	549	-	-

** Significant against pooled error (P=0.01) # Significant (P=0.05) when b=1

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Short communication

Morphology of the diploid and auto tetraploid *Arachis villosa* and their crossability with *Arachis hypogaea*

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Genetic improvement of crops is based on utilising the existing variability and to some extent by the use of induced mutations. Using the characters from wild relatives is generally rare due to labour, interspecific barriers and differences in ploidy level in wide hybridization. Of an estimated 60-70 wild species of groundnut, about 20 have been generally available. *A.monticola* of section *Arachis* and *A.glabrata* of section *Rhizomatacea* alone are tetraploids (2n=40) as that of *A.hypogaea*. However, the species belonging to section *Arachis* alone is cross compatible with cultivated groundnut. As most of the wild species are diploid with 2n=20 chromosomes, the hybrid with the cultivated groundnut will result in almost sterile triploids (2n=30). With an objective to raise the ploidy level of the diploid to that of cultivated groundnut to overcome the ploidy difference (Singh, 1985), chromosomes of *A.villosa* (2n=20) were doubled by colchicine treatment, leading to autotetraploid *A. villosa*. The morphology of the diploid and autotetraploid of *A.villosa* and their F_1 hybrids on hybridization with *A.hypogaea* are presented.

Seeds of *A.villosa* (Accession no. ICG 8144 originated from Argentina) a perennial diploid wild species were sown in pots. At two leaf stage cotton wool was kept around the terminal bud and moistened with 0.4% aqueous solution of colchicine. The application was continued for three consecutive days (Singh, 1986). Of the 15 plants treated with colchicine, two plants which exhibited gigas characters for leaflets and flowers were transplanted in the field. The cytological analysis of these plants revealed that they were autotetraploids.

The pollen of the autotetraploids and diploid species were utilised for hybridization with cv. VRI 4 of *A.hypogaea*. The morphology of the parents and their F_1 hybrids were studied. The screening for disease resistance was carried out under field conditions. There was a good development of the disease from natural inoculum. The materials were rated just before harvest for rust and late leaf spot on a 9-point scale (Subrahmanyam *et al.*, 1982).

The autotetraploid plants exhibited initial slow growth rate followed by vigorous growth. The stem was woody and the leaves were broader, thicker and dark green in colour. The standard petals of the flowers were bigger. The pollen stainability was only 55.0 %. The pollen grains of the tetraploid were 3.2 μ as compared to 2.0 μ of the diploid. The tetraploids started flowering 80 days after planting as against 30 days by the diploids. The pods and kernels were bigger than diploid (Table 1). The progeny of the tetraploid plants continued to maintain larger vegetative and floral parts.

Fertility in autotetraploid was not high inspite of normal separation of quadrivalents in majority of cells and a very low frequency of univalents. No linear relationship could be traced between the meiotic aberrations and the sterility in the tetraploids. Genic factors seem to play a significant role in conditioning sterility in tetraploids (Raman and Kesavan, 1963).

The triploid F_1 plants were vigorous, prostrating with profuse branches. There were abundant flowers in triploids, although peg formation was rare. The pollen stainability ranged from 9 to 14%. The partial fertility may be due to unequal chromosome segregation resulting in the formation of haploid to hyperdiploid gametes and spindle breakdown in turn leading to formation of restitution of nuclei and unreduced gametes. Fertilization between such viable gametes resulted in the partial fertility in triploids (Singh, 1985). The pods of triploids were mostly single seeded and very small in size. The triploids were found resistant to rust and late leaf spot diseases as was also observed by Company *et al.* (1982).

The F_1 of the cv. VRI 4 of *A.hypogaea* and autotetraploid *A.villosa* was compact with decumbent habit of growth. The leaves were broader and light green resembling *A.hypogaea*. The peg formation and pod setting was normal. The pods were two seeded and without much constriction. The plants recorded a grade of 3.5 and 4.0 respectively for rust and late leaf spot as compared to 7.5 and 8.5 in the susceptible check, cv. VRI 2.

Obtaining stable tetraploid from triploid is a tedious and time consuming process. However, by utilising the induced autotetraploid, stable tetraploid progenies could be obtained in the immediate generation. Hence, the autotetraploid route proved to be advantageous over the triploid route in the introgression of *A.villosa* with *A.hypogaea*.

Table 1 Morphological features of diploid and tetraploid *A.villosa* and their hybrids with cv. VRI 4

Character	*A.villosa* (2x)	F_1 of *A.hypogaea* x *A.villosa* (3x)	*A.villosa* (4x)	F_1 of *A.hypogaea* x *A.villosa* (4x)	VRI 4 (4x)
Height of main stem (cm)	25.5	21.0	35.0	24.0	36.0
Number of primary branches	17.0	14.0	18.0	6.0	6.0
Number of Secondary branches	19.0	32.0	10.0	5.0	5.0
Number of tertiary branches	26.0	63.0	17.0	15.0	2.0
Length of primary branches (cm)					
Mean	65.0	90.3	10.6.5	45.3	34.0
Range	36.5-74.0	80.5-101.5	95.0-120.0	35.2-50.3	30.0-36.0
Length of Secondary branches (cm)					
Mean	25.5	42.4	37.1	32.5	17.0
Range	18.0-35.8	30.0-48.1	25.0-40.0	19.3-45.1	15.0-19.0
Length of tertiary branches (cm)					
Mean	12.0	17.5	12.3	15.1	6.0
Range	8.0-16.8	10.6-25.0	9.5-15.1	10.0-19.7	5-7
Length of petiole (cm)	1.8	3.5	1.9	3.6	4.8
Leaflet size (LxB) (cm)	1.8x1.2	2.2x1.3	2.1x1.3	4.3x2.2	5.5x2.4
Length of calyx tube (cm)	5.0	7.7	5.4	4.4	3.5
Standard petal size (LxB) (cm)	1.1x1.0	1.8x1.3	1.7x1.3	1.5x1.1	1.1x0.9
Number of pods/plant	9	5	8	38	15
Pod size (LxB) (cm)	1.3x0.6	1.5x0.8	1.6x0.8	3.0x1.0	3.8x1.2
Kernel size (LxB) (cm)	0.6x0.3	1.0x0.4	1.0x0.7	1.3x0.9	1.5x1.0
100 kernel weight (g)	9.8	10.8	14.4	34.1	38.5
Kernel colour	Rose	Rose	Rose	Rose	Rose
Reaction to diseases (1-9 scale)					
Rust	2.0	3.0	2.0	3.5	5.5
Late leaf spot	2.5	3.5	2.5	4.0	6.5

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Short communication

Variability and character association in sesame (*Sesamum indicum* L.) in Bay-Islands

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Sesame (*sesamum indicum* L.), a major multi-purpose oilseed crop, is grown sporadically in Andamans. Since it is tolerant to moisture stress it has potential in rainfed rice fallow lands in Bay Islands in summer months in the absence of suitable crops and irrigation. In the last three years variability in a set of 14 germplasm lines, for seed yield and other agronomic traits was studied. An attempt was made to assess the variability of different quantitative traits and determine their association with seed yield at genotypic, phenotypic and environmental levels and the degree of direct and indirect influences on the same.

The experiment was carried out at Crop Research Farm of Central Agricultural Research Institute at Bloomsdale, Port Blair (Lat. 11°41"13'.04N;Long. 92°43"30' 16E), south Andaman in three consecutive summer seasons during 1997-'99. Fourteen genotypes collected from Project Co-ordinator, Sesamum and Niger, Jabalpur were used in this study. They were raised in a randomized block design with three replications. Plot size was 3 x 2.5 m with a spacing of 30 x 10 cm between rows and plants. Appropriate agronomic package of practices were adopted. Observations were recorded on days to 50% flowering. At maturity, ten plants were randomly selected and observations on plant height (cm), number of branches plant^{-1}, number capsules plant^{-1}, harvest index, mean capsules weight (g) and seed yield plant^{-1} (g) were recorded. Statistical analyses were carried out with the mean replication values across years. Genotypic variance (σg), phenotypic variance (σp), environmental variance (σc), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance (GA), genotypic and phenotypic correlation coefficient and path analysis were computed (Burton, 1952; Burton and Devane, 1953; Hanson *et al.*, (1956); Al Jibouri *et al.* (1958); Dewey and Lu, 1959; Allard, 1960).

Table 1 Estimates of mean, range, variance components and genetic parameters for different characters in sesame

Character	Mean S.E.	Range	σg	σp	σe	GCV	PCV	H^2	GA	GA in % of mean
Days to 50% flowering	59.93±1.13	51.0-66.60	9.51	11.46	1.95	5.11	5.61	0.828	5.74	9.57
Plant height (cm)	63.0±4.40	46.87-80.20	115.68	164.45	48.77	14.91	17.13	0.757	17.08	26.71
No. of branches plant^{-1}	1.54±0.32	0.10-2.27	0.25	0.40	0.15	32.44	41.21	0.620	0.81	52.58
No. of capsules plant^{-1}	28.36±2.73	17.40-47.60	76.51	87.77	11.26	30.81	32.99	0.872	16.81	59.26
Harvest index	0.32±0.07	0.20-0.53	0.006	0.022	0.016	25.70	37.80	0.462	0.12	37.5
Mean capsule	0.27±0.02	0.19-0.34	13.65	16.58	2.93	17.03	20.28	0.756	0.08	29.88
Seed yield plant^{-1} (g)	3.30±0.50	1.92-4.00	0.56	0.95	0.39	20.53	27.83	0.544	1.03	31.20

A wide range of variation was observed for different characters among the genotypes (Table 1). Maximum range was noticed in number of branches plant^{-1} followed by number of capsules plant^{-1}, seed yield plant^{-1} and plant height. Minimum range was observed in days to 50% flowering. Analysis of variance for different quantitative traits indicated existence of significant variability in all the characters studied. Among the different characters, number of branches plant^{-1} was found to bear maximum GCV followed by number of capsules plant^{-1} and harvest index. Number of branches plant^{-1} registered maximum PCV followed by harvest index and no. of capsules plant^{-1}. GCV along with heritability estimates generally give a better idea about the efficiency of selection (Burton, 1952). In the present study, high heritability values were recorded for number of capsules plant^{-1} followed by days to 50% flowering, plant height and mean capsule weight (Table 1), while number of branches plant^{-1} and seed yield plant^{-1} exhibited moderate heritability values. Johnson *et al.*, (1955) suggested that heritability and GA when calculated together are more useful in predicting the effects of selection. In the present study, plant height showed maximum GA, followed by number of capsules plant^{-1} (Table 1). However, these traits were having high habitability coupled with high GCV and PCV values. They may be used for genetic improvement of sesame directly through selection. Number of branches plant^{-1} registered moderate habitability with maximum GCV and PCV values. Where as, mean capsule weight showed moderate habitability and high GCV and PCV values. Plant height, number of branches plant^{-1}, and number of capsules plant^{-1} and mean capsule weight could be used in selection.

The estimates of correlation coefficient at genotypic, phenotypic and environmental levels of different characters on seed yield are presented in (Table 2). In general, genotypic correlations were found to be higher than the phenotypic correlations except harvest index, similar to earlier reports (Sanjeeviah and Joshi, 1974; Thangavelu and Rajasekaran, 1983). Number of capsules plant^{-1} showed positive correlation at both genotypic and phenotypic levels among all traits studied.

Table 2 Estimates of correlation coefficients at genotypic (r_g), phenotypic (r_p) and environment (r_e) on seed yield plant^{-1}

Character	r_g	r_p	r_e
Days to 50% flowering	0.486	0.359	0.116
Plant height (cm)	0.450	0.398	0.328
No. of branches plant^{-1}	0.193	0.118	0.015
No. of capsules plant^{-1}	0.732**	0.599**	0.392
Harvest index	0.326	0.370	0.416
Mean capsules weight (g)	0.126	0.016	-0.195

The results of path analysis based on the genotypic and phenotypic correlation coefficient (Table 3) revealed that high positive direct effect on seed yield was exerted through number of capsules plant^{-1} and harvest index. However, only number of capsules plant^{-1} was positively correlated with seed yield. Similar results were also reported earlier (Thangavelu and Rajasekaran, 1983). Mean capsule weight was also found to have high positive direct effect on seed yield but genotypic coefficient of correlation of yield was lower than the direct effect (Table 3). Hence, in selection other traits, which have negative effect with this trait, may be considered. The indirect effects of other traits via number of capsules plant^{-1} on seed yield was found to have considerable influence indicating the importance of this character in selection programme. This is in agreement with Gupta and Tilak Raj (1976) and Gupta and Gupta (1977) in sesame. Harvest index also had high direct and indirect effects via other characters on seed yield, which indicated the very importance of this character in modulating seed yield. The direct effects of days to 50% flowering and number of branches plant^{-1} were found to have positive values but of low magnitude. Plant height had negative direct effect on seed yield as reported earlier by Dixit (1975) in sesame. Phenotypic path analysis revealed that harvest index bore maximum positive direct effect on seed yield followed by number capsules plant^{-1} and plant height. Plant height exercised maximum indirect effect on seed yield via number of capsules plant^{-1}. Therefore, these traits may be considered for selection. In the present study, the residual effect over yield was low in both genotypic and phenotypic levels. There could be some more characters, which could influence the seed yield plant^{-1}.

On the basis of variability and genetic parameter studies, correlation and path analysis characters like number of capsules plant^{-1}, harvest index and number of branches plant^{-1} are found to be useful criteria for genetic improvement of sesame.

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Table 3 Direct and indirect effects of different contributing characters towards seed yield in sesame

Character	Days to 50% flowering	Plant height (cm)	No. of branches plant^{-1}	No. of capsules plant^{-1}	Harvest index	Mean capsule weight (g)	r_g and r_p correlation of yield plant^{-1}
Days to 50 % flowering	G **0.123**	-0.082	0.028	0.385	0.053	-0.021	0.486
	P **0.077**	0.150	-0.018	0.142	0.012	-0.004	0.359
Plant height (cm)	G 0.066	**-0.154**	0.036	0.588	-0.215	0.130	0.450
	P 0.034	**0.343**	-0.021	0.226	-0.196	0.013	0.398
No. of branches plant^{-1}	G 0.054	-0.087	**0.064**	0.234	-0.036	-0.038	0.193
	P 0.022	0.111	**-0.066**	0.056	-0.006	0.001	0.118
No. of capsules plant^{-1}	G 0.056	-0.108	0.018	**0.841**	0.013	-0.088	0.732**
	P 0.031	0.219	-0.010	**0.353**	0.026	-0.019	0.599**
Harvest index	G 0.018	0.094	-0.006	0.031	**0.353**	-0.164	0.326
	P 0.002	-0.133	0.001	0.018	**0.505**	-0.022	0.370
Mean capsule	G-0.005	-0.043	-0.005	-0.100	-0.125	**0.464**	0.126
weight (g)	P-0.002	0.036	-0.001	-0.054	-0.089	**0.126**	0.016

G and P : genetic and phenotypic correlations; ** : significant at 0.01 level; Bold figure : direct effects; Residual effect : Genotypic = 0.2082 and Phenotypic = 0.4437

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Short communication

Combining ability for yield related traits in sesame (*Sesamum indicum* L.)

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Sesame (*Sesamum indicum* L) is an important edible oilseed crop grown in India. The present investigation was undertaken to evaluate a few genotypes for their combining ability.

Eight genotypes of sesame *viz.*, CO1, Uma, TMV 3, TMV 6, SVPR 1, TNAU 142, VRI 1 and IVTS 4 were crossed in an 8 x 8 diallel fashion including reciprocals during summer 1998 at Agricultural College and Research Institute, Coimbatore. Eight parents and their 56 hybrids were raised in a randomized block design with three replications during *kharif* 1998. Each entry was sown in four rows of 4.5 m length with a spacing of 45 cm between rows and 30 cm between plants. Data were recorded on five randomly selected plants on days to first and 50% flowering, plant height, number of primary branches, secondary branches, capsules on main stem, capsules on all branches, 1000 seed weight, plant yield, oil content, total dry matter and harvest index. The data were analysed according to Griffing (1956).

The analysis of variance for combining ability revealed that both general and specific combining ability were significant for all the characters except for oil content, whereas *gca* variance was not significant for harvest index (Table 1). This indicated that both additive and non-additive gene action were present for the characters studied which is akin to the results obtained by Fatteh *et al.*, (1995). In the present study *gca* variance was greater than *sca* variance which indicated the predominance of additive gene action in the expression of characters. Similar results were reported earlier (Reddy and Haripriya, 1991; Dharmalingam and Ramanathan, 1993; Imrie, 1995).

None of the parents tested recorded significant *gca* effects for all the characters (Table 2). Co 1 was found to be the best general combiner, recording significant *gca* effects for yield and yield components namely 1000 seed weight, number of capsules on main stem and number of capsules on all branches followed by VRI 1. TMV 3 and TMV 6 were good general combiners for plant yield, number of capsules on all branches and total dry matter. The parents with largest number of desirable alleles will give the best performance and this will be reflected in the better performance of the progeny derived from that parent.

Table 1 Analysis of variance for combining ability

Character	*gca*	*sca*	Reciprocal
Days to first flowering	38.303**	8.823**	11.814**
Days to 50% flowering	38.174**	8.123**	11.586**
Plant height	83.866**	12.907**	17.388**
No. of primary branches	8.835**	4.426**	3.152**
No. of secondary branches	29.937**	11.435**	18.515**
No. of capsules on main stem	4.986**	3.288*	3.715**
No. of capsules on branches	12.731**	2.790**	3.802**
1000 seed weight	9.075**	10.052**	7.307**
Single plant yield	18.397**	5.078**	7.464**
Oil content	0.282	1.250	1.614
Total dry matter	259.798**	35.095**	78.539**
Harvest index	2.144	6.083**	6.198**

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

Uma x TMV 6 showed high *sca* effects for yield and yield related traits like 1000 seed weight and capsules in branches (Table 3). In order to develop early maturing varieties Uma x VRI 1 might serve as the best combination as it had least significant *sca* effect for days to first and 50% flowering. None of the crosses showed significant *sca* effect for oil content. All the high yielding hybrids resulted from one parent with poor and another parent with good combining ability effects. This was due to involvement of non allelic interaction of fixable as well as non-fixable genetic variables for the traits concerned (Sarsar *et al.*, 1986). A diallel cross enables an early

Table 2 General combining ability effects

Character	CO 1	Uma	TMV 3	TMV 6	SVPR 1	TNAU 142	VRI 1	IVTS 4
Days to first flowering	1.414**	-1.589**	1.620**	1.849**	-0.151*	-2.464**	0.432	-1.109**
Days to 50% flowering	1.063**	-0.979**	1.354**	1.708**	-0.271**	-2.500**	0.563**	-0.938**
Plant height	11.126**	-13.719**	2.790**	6.717**	-1.737	-5.336	8.507**	-8.347**
No. of primary branches	0.809**	-0.138	0.381	0.089	-0.203	-0.299	0.217	-0.675**
No. of secondary branches	0.986*	-1.700**	0.688**	0.604	0.171	-0.578	1.245**	-1.146**
No. of capsules on main stem	1.760*	-2.878**	0.428	0.389	0.623	-0.788	0.781	-0.314
No. of capsules on branches	8.314*	-25.858**	14.893**	11.712**	-0.647	-5.637	11.297**	-14.074**
1000 seed weight	0.073**	-0.123**	-0.026	-0.017	0.023	0.021	0.074**	-0.026
Single plant yield	4.739**	-4.209**	0.670**	2.533**	-1.456**	-0.907**	2.788**	-4.155**
Oil content	-0.037	0.075	0.126	0.185*	0.122	-0.056	-0.173	-0.242
Total dry matter	14.757**	-20.049**	5.914**	12.640**	10.325**	-4.262**	13.808**	-12.484**
Harvest index	0.963	0.485	-0.493	-0.196	0.876	0.063	-0.269	-1.430*

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

Table 3 Analysis of variance for combining ability

Character	Cross	Sca effect
Plant height	Co1 x Uma	1.79788
	Uma x SVPR 1	1.693**
	TMV 6 x TNAU 142	2.068**
	Co 1 x IVTS 4	2.151**
Days to 50% flowering	Uma x TNAU 142	-1.661**
	Uma x VRI 1	-2.891**
No. of primary branches	Uma x TMV 3	1.179**
	TMV 6 x TNAU 142	2.290**
	SVPR 1 x VTI 1	2.238**
No. of secondary branches	TMV 6 x TNAU 142	2.290**
	TMV 3 x TNAU 142	1.720**
	SVPR 1 x VTI 1	2.238**
No. of capsules on main stem	Uma x TMV 3	6.136**
No. of capsules on branches	Uma x TMV 6	34.865**
	TMV 3 x TNAU 142	33.887**
	SVPR 1 x VRI 1	40.718**
1000 seed weight	Uma x TMV 6	0.171**
	Uma x TNAU 142	0.270**
	Uma x VRI 1	0.249**
Single plant yield	Uma x TMV 6	8.677**
Oil content	None of the crosses showed significant and positive sca effect	
Total dry matter	Uma x TMV 6	29.717**
	TMV 6 x TNAU 142	29.595**
	SVPR 1 x VRI 1	20.938**
Harvest index	Uma x VRI 1	5.802**

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

decision to be made in choice of parents. Crosses between varieties which have good *gca* effects have the greatest chance of producing superior progeny. Since the genetic variability is due to additive gene action, it can be easily fixed in succeeding generation and advancement could be made using simple selection procedures. As most of the crosses involved one good general combiner, adoption of biparental approach would throw transgressive segregants. Further exploitation of such seggregants would throw lines possessing high yielding ability.

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Short communication

Stability analysis in sunflower (*Helianthus annuus* L.)

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Sunflower is an important oilseed crop grown in both traditional areas namely Karnataka, Andhra Pradesh, Maharashtra and Tamil Nadu and non traditional areas like Punjab and Haryana. Seed and oil yield of sunflower showed high fluctuations over environments. Hence identifying hybrids with good adaptability is essential. In the present study, an attempt was made to evaluate the nature and magnitude of G x E interaction and stability of performance for seed and oil yield of 19 hybrids of sunflower.

The material comprised of 19 hybrids raised in a randomised block design with four replications at four different locations (Coimbatore, Bhavanipatna, Kurnool and Annamalainagar) during *rabi* / spring 1997-98. Each entry was raised in five rows of 3 m length with an inter an intra row spacing of 60 and 30 cm, respectively. All the recommended package of practices was adopted to raise a healthy crop. Observations on seed yield (kg/ha) and oil yield (kg/ha) were recorded on plot basis in each replication and statistical analysis was done following Eberhart and Russell (1966). For oil yield, data from three locations (except Annamalainagar) were obtained and used for analysis.

Pooled analysis of seed yield and oil yield (Table 1) revealed that all the hybrids, environments differed and interacted significantly. Among the components of G x E interaction i.e., G x E (linear) and pooled deviation, the variance due to pooled deviation alone registered significance for both the characters. It indicated that the performance of genotypes in each environment could be difficult to predict due to the preponderance of non-linear component for both the characters.

Table 1 Analysis of variance for stability in sunflower

Source	Seed yield (kg/ha)		Oil yield (kg/ha)	
	df	Mean squares	df	Mean squares
Genotype (G)	18	103156**	18	16738**
Environment (E)	3	2089151**	2	454358**
Environment + G x E	57	80835**	38	106034**
Environment (Linear)	1	6267445**	1	2479
G x E (Linear)	18	98347	18	13604
Pooled deviation	38	68285**	19	7202**
Pooled error	152	31049	114	2479

** Significant at 1% level

1&2 AICRP (Sunflower). CPBG, TNAU, Coimbatore-641 003
3 RRS, OUAT, Bhawanpatna-766 001
4 ITC-Zeneca, Kurnool, AP
5 A U., Annamalainagar-608 002

The mean, regression coefficient (b) and the deviation from regression for oil and seed yield are presented in Table 2. According to Eberhart and Russell (1966), a stable variety should have high mean, stable performance ($s^2d=0$) and average responsiveness to environment. In the present study, 11 and five hybrids recorded high mean (significantly on par) and non significant squared deviation from regression ($s^2d=0$) for seed and oil yield respectively. Among hybrids, MSFH 17, New Bhavani 3, Jwalamukhi and SH 187 recorded high mean and stability for seed and oil content. Hence, these hybrids should be given importance for recommendation. The hybrids, New Bhavani 3, Jwalamukhi and SH 187 recorded average responsiveness to environment (b=1), while hybrid MSFH 17 showed above average responsiveness to environment (b>1) for both oil and seed yield. Hence the hybrids, New Bhavani 3, Jwalamukhi and SH 187 could be recommended for all locations, while the hybrid MSFH 17 could be recommended to highly favourable environment alone.

To conclude, the present study revealed that the hybrids, environments differed and interacted significantly. In general, the performance of genotypes could not be estimated due to the preponderance of non linearity. The hybrids, New Bhavani 3, Jwalamukhi and SH 187 recorded high mean and stability for oil and seed yield and could be recommended to all environments due to their average responsiveness and the hybrid MSFH 17 could be recommended to highly favourable environment due to above average responsiveness to environment.

Reference

Eberhart S.A. and Russel, W.A. 1966. Stability parameters for comparing varieties. *Crop Science*, **6**:36-40.

Table 2 **Stability parameters for seed and oil yield in sunflower**

Genotype	Seed yield (kg/ha)			Oil yield (kg/ha)		
	Mean	bi	s^2di	Mean	bi	s^2di
MSFH 17 C	1399 a	2.1 #	18173	627 a	2.0 #	5552
Jwalamukhi C	1320 a	1.2	938	557 a	1.2	7231
KBSH 1 C	1361 a	1.4	-6672	579 a	1.5	11621*
Bioseed 5468	1283 a	1.8	116784**	623 a	1.2	15782**
PAC 36	1485 a	0.9	165172**	689 a	1.1	21965**
New Bhavani 3	1268 a	0.8	-19522	531 a	0.7	-1643
VSF 401	1090	1.0	23881	461	0.7	-1545
SH 187	1332 a	0.5	-9672	528 a	0.6	158
KBSH 35	1129 a	-0.2 #	-13534	453	-0.1 ##	14758**
PSFH 10	1118	1.2	-21352	464	1.1	-1907
PG 1045	998	0.2	-25078	415	0.3	2323
KBSH 38	1362 a	0.9	39476	521	1.0	-1594
PSH 53	1465 a	0.4	224448**	530 a	0.7	-2287
KDSFH 13	1191 a	1.0	24713	490	0.6	-2257
KBSH 39	1516 a	1.3	104991*	613 a	1.8	12118*
AH 333	1470 a	0.8	95656*	522	1.0	-2450
MSFH 53	1192 a	1.2	-21316	517	1.2	-2199
KBSH 40	1543 a	1.7	-14666	662 a	1.8 #	9849*
Mega 801	1136 a	0.9	25069	488	0.6	4275
Mean	1298	-	-	540	-	-
SEm.±	151	0.45	_	60	0.6	-
CD (0.05)	418	-	-	166	-	-

Means indicated by similar letters are in par. C = check
bi = regression coefficient
S^2di = squared deviation from regression.
*, ** significant at 5 and 1 per cent. respectively against pooled error.
#, ## significant at 5 and 1 per cent, respectively while b=1.

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Short communication

Screening of sunflower *cms* lines, restorers, populations and hybrids against *Alternaria helianthii* (Hansf.)

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Sunflower (*Helianthus annuus* L.) is the second most important edible oilseed crop in the world after soybean. In India the crop was introduced in early seventies with the introduction of open pollinated varieties like Peridovik and Armavirskii. Sunflower is cultivated over an area of 2.4 million ha with a production of 1.8 million tonnes in India. The crop being photoinsensitive, salinity tolerant, short duration makes it more advantageous to farmers. The crop was introduced in Haryana in 1990 and now it has become a major oilseed crop of this region. The value of hybrids and importance of hetrosis breeding was recognised with the inception of All India Co-ordinated Research Project on Oilseeds (AICORPO). Many hybrids such as BSH-1, APSH-11, MSFH-17, KBSH-1 are under cultivation in India.

Although sunflower has been very successful, diseases are limiting its productivity. Amongst diseases, alternaria leaf spot, *Alternaria helianthii* (Hansf.) Tubaki and Nishihara (1969) is the most serious. Under epiphytotic conditions, yield losses upto 80% have been reported and all the currently grown varieties and hybrids are susceptible to it (Balasubramanayam and Kolte, 1980). Typical leaf symptoms are necrotic spots, often surrounded by chlorotic halo, which under favourable conditions get enlarged and coalesce so that large areas of the foliage are destroyed (Herr and Lipps, 1982). This disease significantly reduces the head diameter, number of seeds produced per head, 100 seed weight and oil content (Balasubramanayam and Kolte, 1980). The pathogen is present in all the sunflower growing regions of the world and most of the cultivated varieties are susceptible. Keeping in view the above different available lines of sunflower were screened against the leaf spot disease.

The seed material consisting of seven populations (EC 132847, EC 126184, EC 68415B, Surya, Morden, EC 68414 and EC 68415C), six *cms* lines (CMS 851A, CMS 336A, CMS 290A, CMS 207A, CMS 7-1A, CMS 338C) and thirteen restorer lines (RHA 297, RHA 271, P28R, RHA 856, RHA 857, 83 R 6, RHA 273, RHA 298, RHA 586, RHA 6D-1, RHA 274, RHA 296, RHA 347) of sunflower lines were used in the present study.

The F_1 crosses were produced among these lines and the material was raised during February, 1996-97 both under field and net house conditions. The fungus for *alternaria* blight was obtained from infected leaves of sunflower grown at research farm of CCSHAU, Hisar.

The infected leaves were brought in laboratory, washed with tap water and then with distilled water. Lesions of 5-10 mm square were cut down from infected leaves. These beads (infected portion) were surface sterilized and transferred to potato-dextrose agar medium. After several days of incubation desired type of fungus was selected and multiplied on PDA broth.

To ensure the occurrence of disease, the crop grown in green house was artificially inoculated with alternaria spores by spraying the inoculum on 40 days old plants. The inoculum was prepared by crushing 2.0 g of alternaria spores in 100 ml of water. Protected healthy plants were taken as control. In all three sprays were given at an interval of three days. The successive lesion development was observed after inoculation and disease index was computed on 0-9 scale as follows:

Per cent leaf area infected	Score	Disease reaction
Zero	0	Immune
Less than 1%	1	Highly resistant
1 to 5%	3	Resistant
5 to 25%	5	Moderately resistant
25 to 50%	7	Susceptible
More than 50%	9	Highly susceptible

The percent disease intensity (P.D.I) was calculated by using formula given by McKinney (1923).

The experiment was laid out in completely randomised design with three replications. The data were analysed for mean, standard error and critical difference to compare variation among genotypes.

The results presented in table 1 indicated the reaction of sunflower populations, fertility restorer lines, male sterile lines and hybrids to alternaria blight under artificially inoculated conditions against the disease. All the lines and hybrids were assessed visually for percent disease intensity and their reaction was determined.

Table 1 Performance of sunflower populations, fertility restorers, male sterile lines and their crosses against *Alternaria helianthii* under green house conditions

Genotype	Disease intensity (%)/ reaction	Genotype	Disease intensity (%)/ reaction
Populations		**CMS lines**	
EC 132847	1.38/R	CMS 851A	2.84/R
EC 126184	1.51/R	CMS 336A	3.04/R
EC 68415B	4.78/R**	CMS 290A	3.24/R
Surya	15.75/MR.S**	CMS 207A	3.41/R
Morden	21.47/MR.S**	CMS 7-1A	4.66/R**
EC 68414	32.14/S**	CMS 338C	4.96/R**
EC 68415C	43.55/S**		
S.E.d=0.379,	C.D.(0.01)=1.12;(0.05)=0.81	S.E.d=0.541,	C.D.(0.01)=1.65; (0.05)=1.18
Restorer lines		**Crosses**	
RHA 297	2.99/R	CMS 7-1AxEC 132847	2.18/R
RHA 271	3.44/R*	CMS 336AXEC 126184	2.30/R
P2 8R	4.22/R**	CMS 7-1AXEC 126184	2.43/R
RHA 856	4.77/R**	CMS 7-1AXRHA 265	2.99/R**
RHA 857	7.07/MR-S**	CMS 7-1 AXRHA 347	3.22/R**
83 R 6	8.19/MR-S**	CMS 7-1 AXRHA 272	3.30/R**
RHA 273	9.62/MR-S**	CMS 7-1 AXRHA 857	3.44/R**
RHA 298	15.75/MR-S**	CMS 851 AXRHA 265	3.82/R**
RHA 586	20.95/MR-S**	CMS 336 AXRHA 265	4.41/R**
RHA 6D-1	21.24/MR-S**	Morden x Surya	4.76/R**
RHA 274	23.27/MR-S**	CMS 7-1 AXEC 68414	10.32/MR-S**
RHA 296	24.36/MR-S**	EC 68414xRHA 271	17.35/MR-S**
RHA 347	38.76/S**	CMS 851A x RHA 272	23.77/MR-S**
S.E.d=0.359	C.D.(1%)=1.25;(5%)=0.73	S.E.d=0.45	C.D.(1%)=1.25;(5%)=0.927

R=Resistant: MR-S= Moderately resistant-susceptible; S=Susceptible, *, ** Significant at five and one %, respectively.

Of seven populations screened for alternaria disease, three were found to be resistant (EC 132847, EC 126184, EC 68415B), two were moderately resistant (Surya and Morden) and two were susceptible (EC 68414, EC 68415C). The disease intensity in these *populations ranged* from 1.38 to 43.55 % indicating resistant and susceptible disease reactions, respectively. Two resistant populations (EC 132847, EC 126184) were found to be non significantly different from each other but all other lines were significantly different from population, EC 132847. Out of thirteen fertility restorer lines studied, four lines showed resistant reaction (RHA 297, RHA 271, P2 8R, RHA 856) and only one line (RHA 347) showed susceptible reaction, whereas all other lines showed moderately resistant reaction. The disease intensity of these lines ranged from 2.99 to 38.76 %. It was also observed that 11 restorer lines were significantly different from *line RHA 297* at 1 % level of significance, while RHA 271 was significantly different from RHA 297 at 5 % level of significance. The resistance of restorer line RHA 271 seems to be real and additive as EC 68414 was susceptible genotype whereas their hybrid combination (EC 68414 x RHA 271) was found to be moderately resistant.

All the CMS lines exhibited resistant disease reaction and the lines CMS 7-1A and CMS 338C were significantly different from CMS 851A. The disease intensity for CMS lines ranged from 2.84 to 4.96 %. The resistance of CMS lines was also found to be dominant because when the line *CMS-7-1A* was crossed with susceptible restorer line (RHA 347) or with moderately resistant restorer line (RHA 857) the resultant hybrid was resistant. In the same analogy, when crosses *viz.*, CMS 7-1 A x EC 132847, CMS 336 x EC 126184 and CMS 7-1A x EC 126184 were screened, the resultant population as expected showed low *disease intensity* and resistant reaction.

From the 13 hybrids studied, ten were significantly different from cross CMS 7-1A x EC 132847, out of which three were moderately resistant and seven were resistant. Two hybrids i.e. CMS 336A x EC 126184 and CMS 7-1 A x EC 132847 showed resistant disease reaction.

The disease intensity for hybrids ranged from 2.18 to13.77%. It was observed that when moderately resistant lines (Morden and Surya) were crossed, their F_1 hybrid gave resistant disease reaction. This shows that genes for resistance to alternaria blight are dispersed differently and in hybrid combinations the favourable allieles get accumulated to give resistant disease reaction. The crosses that involved one resistnat cultivar (CMS 7-1A) was crossed with susceptible cultivar (RHA 857) their F_1 again showed resistant reaction. So it can be concluded that resistance to alternaria is polygenically controlled and dominance phenomenon is expressed in hybrids. Carson (1985) reported that although differences were found between inbred lines for reaction to disease, no significant differences were detected between fertile sunflower inbreds and their CMS counterparts in resistance to alternaria blight. Nagaraju *et al.* (1993) suggested that hybrids performed better in response to their resistance to leaf spot and that such resistance was derived either from the CMS or restorer lines used in their production. However Ravi Kumar *et. al.* (1995) suggested that an alternate strategy is needed to utilise the available low level of resistance. From the present study it was observed that selected lines showed varied level of resistance and none exhibited either immune or highly resistant reaction to disease.

This suggested that a *wide variability to* alternaria leaf spot exhibited in lines selected, but few lines and their hybrids appeared promising against this disease. In the near future, the exploitation of wild sources will be most promising, especially for disease resistance, which can be easily transferred by backcross procedures. Morris *et.al* (1983) reported that wild perennial *Helianthus* spp. can be utilised and resistance could be transferred to cultivated sunflower by backcross breeding of inbreds with resistant perennial species.

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Short communication

Response of groundnut crop to organic and inorganic fertilizers under *irrigated conditions*

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In India, groundnut crop occupies nearly 8.5 m.ha and *contribute to the tune of 7.9 m.t to oilseeds production.* Inadequate and imbalance use of nutrients is one of the main reasons for low yield in groundnut. Organic manures are considered to be the source of complete plant food as they provide almost all essential major and minor nutrients and sustains the fertility of soil. Application of FYM improved the yield attributes and yield of groundnut (Chittapur *et al.*, 1993). Higher pod yield was obtained with application of adequate major nutrients to groundnut crop (Rao and Moorthy, 1994). Maximum test weight and number of filled pods plant^{-1} were recorded with split application of phosphorus as compared to only basal application (Chitkala Devi *et al.*, 1987). Groundnut requires supplemental calcium during pod formation stage. Application of gypsum in addition to major nutrients significantly increased the number of kernels pod^{-1}, kernel weight and pod yield as compared to NPK application alone (Sushila, 1992). Hence, an attempt has been made to study the effect of combined use of organic and inorganic sources of nutrients as well as optimal time of phosphorus and gypsum application on yield attributes and yield of irrigated groundnut.

The experiments were carried out during summer, 1996 and *rabi*, 1997 at Agricultural College and Research Institute, Killikulam, Tamil Nadu. The soil of the experimental site was red sandy loam, low in available nitrogen, medium in available phosphorus and high in available potassium. Groundnut cv. TMV 7 was selected for this study. The experiment was laid out in randomized block design with 12 treatments involving NPK treatments in the presence and absence of FYM and gypsum in three replications as shown below:

Treatment	Basal NPK (kg ha^{-1})	FYM (t ha^{-1})	P on 30 DAS (kg ha^{-1})	Gypsum on 40 DAS (kg ha^{-1})
T_1	17 : 34 : 54	-	-	-
T_2	17 : 17 : 54	-	17	-
T_3	17 : 17 : 54	-	17	400
T_4	17 : 34 : 54	12.5	-	-
T_5	17 : 17 : 54	12.5	17	-
T_6	17 : 17 : 54	12.5	17	400
T_7	34 : 34 : 54	-	-	-
T_8	34 : 17 : 54	-	17	-
T_9	34 : 17 : 54	-	17	400
T_{10}	34 : 34 : 54	12.5	-	-
T_{11}	34 : 17 : 54	12.5	17	-
T_{12}	34 : 17 : 54	12.5	17	400

The groundnut seeds were sown at a spacing of 30 x 10 cm. The recommended package of practices was followed for raising a healthy crop.

In both the seasons, significant increase in yield attributes was observed due to variation in fertilizer levels and time of their application, FYM and gypsum application (Table 1). The fertilizer schedule of 34:17:54 kg NPK ha^{-1} + FYM 12.5 t ha^{-1} (as basal) + 17 kg P_2O_5 kg ha^{-1} on 30 DAS + 400 kg gypsum ha^{-1} on 40 DAS produced significantly more number of matured pods plant^{-1}, pod weight plant^{-1}, number of kernels pod^{-1} and test weight. The same fertilizer schedule without gypsum application was found to be the next best in recording higher values of yield attributes. In both the seasons recommended level of fertilizer (17:34:54 kg NPK ha^{-1}) recorded lowest values of yield attributes in groundnut. This response could be due to greater photosynthetic rate and maximum utilization of phosphatic fertilizer by the groundnut crop. The present findings corroborated with the observations of Thimmegowda (1993).

Table 1 **Effect of organic manure, fertilizer levels, split application of phosphorus and gypsum on yield attributes and yield of groundnut under irrigated condition**

Treatment	No. of mature pods plant^{-1}		Pod weight plant^{-1} (g)		No. of kernels pod^{-1}		100 kernel weight (g)		Pod yield (kg ha^{-1})		Haulm yield (kg ha^{-1})	
	Summer 1996	*Rabi* 1997	Summer 1996	*Rabi* 1997	Summer 1996	*Rabi* 1997	Summer 1996	*Rabi* 1997	Summer 1996	*Rabi* 1997	Summer 1996	*Rabi* 1997
T_1	14.19	12.17	5.80	5.47	1.05	0.99	28.60	27.10	1412	1313	2671	2489
T_2	14.23	12.23	5.83	5.53	1.51	1.43	28.83	27.23	1495	1367	2723	2586
T_3	14.32	12.55	5.87	5.57	1.64	1.55	28.86	27.30	1582	1401	2991	2594
T_4	14.45	12.91	5.89	5.58	1.66	1.57	28.91	27.71	1595	1481	3045	2619
T_5	14.53	13.05	5.95	5.61	1.69	1.58	28.98	27.95	1610	1508	3126	2865
T_6	14.61	13.17	6.10	5.73	1.75	1.66	29.06	27.98	1654	1651	3285	2918
T_7	14.65	13.38	6.20	5.82	1.80	1.71	29.26	27.51	1690	1682	3298	3066
T_8	14.73	14.03	6.25	5.95	1.87	1.76	29.26	27.71	1742	1706	3385	3132
T_9	15.19	14.25	6.37	5.99	1.95	1.83	29.50	28.28	1794	1789	3421	3237
T_{10}	15.27	14.47	6.54	6.14	2.00	1.88	29.43	28.85	1810	1794	3510	3290
T_{11}	15.43	14.73	6.81	6.43	2.02	1.91	29.56	28.88	1854	1809	3618	3360
T_{12}	16.08	14.95	7.50	7.09	2.30	2.17	30.23	28.94	1902	2015	3998	3608
SED	0.027	0.022	0.023	0.021	0.024	0.021	0.198	0.186	12.24	11.46	20.71	19.10
CD (0.05)	0.055	0.045	0.047	0.043	0.049	0.043	0.403	0.374	24.90	23.32	42.13	38.85

Among the different treatments, higher pod yield of groundnut (2015 kg ha^{-1} and 1902 kg ha^{-1} in Summer and *rabi* seasons, respectively) was obtained with application of 34:17:54 kg NPK ha^{-1} + FYM 12.5 t ha^{-1} (as basal) + 17 kg P_2O_5 ha^{-1} on 30 DAS + 400 kg gypsum ha^{-1} on 40 DAS which was 42.7 and 44.8% higher than the recommended fertilizer level (17:34:54 kg NPK ha^{-1}). This might be due to higher number of matured pods $plant^{-1}$, filled pods $plant^{-1}$, kernel weight pod^{-1}, test weight and lower number of immature pods. These results conform with the findings of Chawale et al. (1993). Above treatments also gave higher haulm yield of 3998 kg ha^{-1} in summer and 3608 kg ha^{-1} in *rabi* season. This is due to increased dry matter accumulation and better root and shoot growth and maximum utilization of applied nutrients. Lower haulm yields were obtained when recommended level of fertilizer alone was applied during both the seasons. It can be concluded that application of FYM @ 12.5 t ha^{-1} (as basal) + 34:17:54 kg NPK ha^{-1} +17 kg P_2O_5 ha^{-1} on 30 DAS+400 kg gypsum ha^{-1} on 40 DAS helped in realisation of higher yield in groundnut.

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Short communication

Response of sunflower (*Helianthus annuus* L.) to nitrogen and phosphorus in winter season

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Cultivation of sunflower is gaining popularity in Orissa owing to its short duration, photo and thermo insensitivity, wider adaptability and high yielding ability and quality edible oil. Since, sunflower is a new introduction in the state, its agronomic requirements including mineral nutrition need to be standardised. The present study was therefore undertaken to find out the nitrogen and phosphorus requirement of sunflower during the winter season.

A field experiment comprising 16 treatment combinations of four levels each of nitrogen (0, 30, 45, 60 kg/ha) and P_2O_5 (0, 30, 60, 90 kg/ha) was conducted at the OUAT Regional Research Station, Chiplima, Sambalpur, Orissa during winter season of 1993-94. The layout was in randomised block design with three replications. The soil of the experimental plot was sandy loam with pH 5.8, total nitrogen 0.06% and available P and K of 22.8 and 206.6 kg/ha, respectively. Hybrid NSFH-2 was grown as the test crop with a spacing of 45 cm x 25 cm and a common dose of 30 kg K2O/ha. The crop was sown on 1st January, 1994 and harvested on 25th April, 1994 after attaining maturity. Half N and full P_2O_5 and K_2O were applied through urea, single super phosphate and muriate of potash, respectively at the time of sowing. Rest half N was given at 30 days after sowing.

The crop was kept free from incidence of major insect pests and diseases through appropriate plant protection measures.

Effect of nitrogen

Plant height and head diameter increased with successive increment in N dose up to 90 kg/ha. Filled seeds/head, 1000-seed weight and seed weight/plant, however, increased up to 60 kg N/ha and further increased in the dose of N had no beneficial effect (Table 1).

Table 1 Effect of nitrogen and phosphorus on yield attributes and yield of sunflower cv. NSFH-2

Treatment	Plant height (cm)	Head diameter (cm)	Filled seeds/head	Unfilled seeds/head	1000-seed weight (g)	Seed weight head (g)	Seed yield (kg/ha)
N levels (kg/ha)							
0	134.6	7.6	294.6	81.3	25.7	7.8	625
30	140.6	9.2	455.1	66.7	30.1	14.0	974
60	146.8	10.0	500.6	88.3	34.5	16.6	1218
90	160.7	11.5	503.3	87.6	33.8	17.9	1233
CD (0.05)	7.9	0.78	32.9	NS	4.4	2.29	102
P2O5 levels (kg/ha)							
0	139.2	9.	399.2	75.9	29.6	12.2	1780
30	146.4	9.5	415.6	77.0	29.9	12.8	985
45	146.8	9.7	453.2	94.2	32.4	15.1	1128
60	150.2	9.9	485.7	76.8	35.3	16.1	1146
CD (0.05)	NS	NS	32.9	NS	NS	2.29	102

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Nitrogen had no significant effect on unfilled seeds per head. On an average 16 % achenes remained sterile. The sterility percentage was more (22%) in the absence of nitrogen application than with nitrogen (14%). Application of 30 and 60 kg N/ha increased seed yield by 55.8 and 95.9% over control (no nitrogen). Further increase in N dose to 90 kg/ha offered no additional advantage over 60 kg/ha. Such increase in yield might be due to increased availability of N, causing accelerated photosynthetic rate and thus leading to more production of carbohydrates (Sarkar *et al.*, 1995). The results confirm the findings of Khokani *et al.* (1993) and Mishra *et al.* (1995).

Effect of phosphorus

Application of phosphorus had no significant effect on plant height, head diameter, unfilled seeds/head and 1000-seed weight. It however, significantly improved filled seeds/head and seed weight per plant up to 45 kg P_2O_5/ha (Table 1). Maximum seed yield was obtained with 60 kg P_2O_5/ha which was at par with 45 kg P_2O_5/ha. Application of 30, 45 and 60 kg P_2O_5/ha increased seed yield by 26.3, 44.6 and 47.0%, respectively over no P application. This might be due to better below ground plant growth. P being an essential constituent of nucleic acids, phytin, phospholipids and enzymes is responsible for root development and seed formation (Naphade and Waphade, 1991). Similar results were reported by Mishra *et al.* (1995) and Tomar *et al.* (1997). The interaction effect of nitrogen and phosphorus on growth, yield attributes and yield was non-significant indicating that response to either nutrient was independent of the level of the other.

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Short communication

Micronutrient uptake in seed of sunflower (*Helianthus annuus* L.) hybrids

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Sunflower is an important oilseed crop in India. The area under the crop is expanding and cultivation is extended to even marginal soils having low organic matter and poor fertility. Nutrient stress is one of the key factors that limit the crop yield. Monitoring nutritional balances both in the plant and soil are useful in their efficient management to realize higher seed yield. Significant responses of sunflower to soil application of macro and micronutrients were reported (AICORPO, 1990-95). Micronutrients, especially zinc has been reported to have a significant influence on seed yield and oil content (Tandon, 1995). The magnitude of response/uptake to applied of native available zinc and other microntrients is governed by several factors viz., sensitivity of crop and their cultivars, soil types and their nutrient status, soil environment, climate, cultural practices and nutrient interactions etc. (Takkar *et al.*, 1989). In the present studies micro nutrient contents and their uptake by seed of sunflower hybrid vis-a-vis nutrient bioavailability have been examined.

Seeds of different sunflower hybrids viz. AS-471, PAC-2514, PAC-6753, AS-468, AS-440 and two checks KBSH-1, MSFH-17 (*kharif*, 1995) cultivated in different soils of low to medium fertility status and agro-climatic conditions viz. Amreli (Gujarat plain and hills), Akola, Koparagaon (Western plateau and hills), Bangalore, Coimbatore and Nandyal (Southern plateau and hills) were collected. Four important micronutrients zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) in the seeds were analysed by following standard procedures (Jackson, 1965). Oil content was determined by NMR method. Nutrient uptake by seed was calculated using the seed yield obtained at these locations (AICORPO, 1995-96). The nutrient use efficiency (NUE) was also computed. Statistical analysis for the individual nutrient contents and uptake were carried out by following standard methods (Panse and Sukhatme, 1967).

Zinc : Significant differences in the Zn content of seeds among different locations were observed (Table 1). However, Zinc content among different hybrid seeds did not differ significantly. Lowest Zn content was recorded at Bangalore (42.3 mg kg^{-1}) while highest was recorded at Akola (88.4 mg kg^{-1}). Differences in uptake of Zn among sunflower hybrids were not found significant. However, the Zn uptake by hybrids grown at different locations varied significantly. Zinc uptake by the hybrids was lowest at Nandyal (51.7 g ha^{-1}) while higher uptake was noticed at Coimbatore (129.1 g ha^{-1}). Among the hybrids, the NUE of Zn was highest in AS-471 and PAC-6753 and lowest in MSFH-17 (Table 2). Among the locations highest NUE of Zn was noticed at Akola, while lowest NUE of Zn was observed at Bangalore. The data indicated that location effects were very specific compared to the difference among the hybrids.

Iron : Though the Fe content varied from 12.7 mg kg^{-1} to 21.6 mg kg^{-1} among the different hybrids, they were non significant. Iron content in seeds was not influenced by location differences either. A significant difference in the uptake of Fe by the different hybrid seeds was noticed. The uptake pattern was also significant among different locations tested. Seed uptake of Fe was highest in hybrid AS-417 (43.2 g ha^{-1}) and lowest in check hybrid KBSH-1 (18.5 g ha^{-1}). Uptake of Fe among different locations followed the order: Kopargaon> Amreli> Bangalore> Coimbatore> Akola> Nandyal. The lowest NUE of Fe was observed at Kopargaon and highest at Akola (Table 2). A higher NUE is an index of more availability of the nutrients in the soil solution and efficient partitioning of the absorbed nutrient between the vegetative and reproductive parts of crop plants.

Manganese : Concentration of Mn among different sunflower hybrid seeds varied from 14.5 mg kg^{-1} to 18.1 mg kg^{-1} showing significant differences among them. Manganese content was highest in the hybrid seeds of Nandyal (24.3 mg kg^{-1}) while the lowest Mn content was recorded in Akola (12.9 mg kg^{-1}). Manganese content in PAC-6753 hybrid seeds was higher i.e. 18.1 mg kg^{-1} than the check hybrids KBSH-1 and MSFH-17 (Table 1). Uptake of Mn by different hybrid seeds followed the order AS-471-MSFH-17>KBSH-1>PAC-2514> PAC-6753 AS-440>AS-468. The Mn uptake among locations and hybrids varied significantly. Highest Mn uptake (32.7 g ha^{-1}) by the seeds was recorded at Kopargaon, while the lowest uptake was recorded at Akola (13.3 g ha^{-1}). Manganese nutrient use efficiency was highest in PAC-6753, while it was lowest in AS-440. Among the locations, sunflower at Nandyal had the highest NUE of Mn while lowest NUE of Mn was recorded at Bangalore (Table 2).

Copper : Concentration of copper among the different hybrid seeds ranged from 15.9 mg kg^{-1} (MSFH-17 check) to 22.2 mg kg^{-1} (PAC-2514). Compared to the check hybrids (KBSH-1 and MSFH-17), the hybrids tested recorded higher Cu content in the seeds. Significant differences in Cu content among the hybrid seeds were observed. Effect of location was also found significant on the content of Cu (Table 1). The Cu content of sunflower seed was lowest at Bangalore (12.7 mg kg^{-1}) while it was highest at Kopargaon (25.4 mg kg^{-1}). Uptake of Cu by the hybrid seeds differed significantly among the locations too. However, Cu uptake among different hybrid seeds was not significant. Uptake of Cu by hybrids at different locations followed the order: Coimbatore> Kopargaon>Amreli> Bangalore>Akola>Nandyal. The NUE of Cu was highest in PAC-2574 and lowest in check hybrid MSFH-17. The NUE of Cu was highest and lowest at Kopargaon and Bangalore locations, respectively (Table 2).

Table 1 Micronutrient content, uptake, seed yield and oil content in sunflower hybrid seeds

	Micronutrient content (mg kg^{-1})				Micronutrient uptake (g ha^{-1})				Seed yield (kg ha^{-1})	Oil content (%)
	Zn	Fe	Mn	Cu	Zn	Fe	Mn	Cu		
Hybrid										
AS-440	59.7	16.5	14.5	20.0	88.8	25.6	21.1	30.9	1525.8	39.6
KBSH-1	62.4	12.7	17.8	18.6	86.6	18.5	24.8	28.3	1544.0	38.0
PAC-6753	64.8	19.0	18.0	19.7	91.8	30.0	24.8	29.7	1457.3	37.5
AS-471	63.7	21.5	16.9	20.4	113.4	43.2	29.3	37.9	1805.8	37.6
MSFH-17	57.3	20.8	15.1	15.9	102.3	40.0	27.83	31.1	1890.3	32.4
AS-468	63.3	19.7	15.3	20.2	92.1	30.5	24.1	33.0	1620.0	39.8
PAC-2514	62.5	19.2	16.1	22.1	93.1	30.0	24.8	35.0	1592.6	37.0
C.D. (0.05)	NS	NS	2.2	3.0	NS	14.9	4.3	NS	NS	1.9
Location										
Amreli	60.1	19.1	14.5	18.5	123.7	39.8	29.7	38.2	2066.3	40.7
Bangalore	42.3	20.5	13.8	20.7	79.7	38.5	26.0	23.9	1882.6	40.0
Akola	88.4	14.4	13.0	17.5	91.0	14.8	13.3	18.1	1040.4	43.2
Nandyal	71.2	16.7	24.3	20.0	51.7	12.7	16.8	13.9	702.7	26.6
Coimbatore	56.9	15.5	15.6	23.4	129.1	35.1	32.7	52.8	2281.6	38.5
Kopargaon	52.9	24.7	16.3	25.5	97.6	45.9	29.9	46.6	1828.7	35.5
S.Em±	12.9	7.3	1.8	2.5	21.3	12.6	3.7	6.2	345.3	1.6
C.D. (0.05)	14.07	NS	2.0	2.8	23.2	13.8	4.0	6.9	376.9	1.7

Seed yield : Seed yield among the different locations followed the order: Coimbatore> Amreli> Bangalore> Kopargaon>Akola>Nandyal and the differences were significant (Table 1). Among the hybrids, AS-471 and MSFH-17 recorded the highest seed yield although the seed yield differences were not significant among different hybrids.

Oil content : Oil content in the hybrid seeds differed significantly when compared with KBSH-1 and MSFH-17 (Check hybrids). All other tested hybrids recorded relatively higher oil content. The oil content at various locations followed the order: Akola>Amreli>Bangalore> Coimbatore>Kopargaon> Nandyal and it was found varying significantly (Table 1).

Micronutrient uptake ratios in sunflower seeds (Table 2) revealed that the ratio of Zn: Fe was highest in KBSH-1 and lowest in MSFH-17 (Check hybrids). Among the test hybrids, AS-471 seeds recorded lowest Zn: Fe ratio (2.62). The Zn: Mn uptake ratio was lowest in KBSH-1, while it was highest in AS-440. The hybrid PAC-6753 recorded lowest Zn: Mn ratio among the test hybrids. The uptake ratio of Zn: Cu was lowest in PAC-2574 while it was highest in MSFH-17 (Check hybrid). Among the locations, the uptake ratios of Zn: Fe, Zn: Mn and Zn: Cu were highest at Akola, while lowest ratios of Zn: Fe and Zn: Mn were recorded at Bangalore. Higher nutrient ratios of Zn: Fe, Zn:Mn indicated more availability of Zn over Fe and Mn as a result of synergistic effect among different micronutrients leading to sometimes deficiency of either Fe or Mn or both, which can be corrected through foliar spray. The correlation studies both for hybrids and locations showed a non-significant and negative correlation of Zn and Mn and a positive correlation of Fe with seed yield. The interactive influence of zinc on Mn content of sunflower seed was significant and positive (0.695*). Scherer and Hoefner (1980) suggested that in the micronutrient interaction studies the reciprocal effects of the elements not only on the other element concentration but also on its total accumulation should be considered.

In general, Zn content and uptake were highest at all the locations and in all the hybrids studied. Accumulation and uptake of Mn in the sunflower hybrid seeds was lower, probably due to its less mobile nature in the plant (Wittwer and Teubner, 1959) or due to the antagonistic nutrient interactions (Hewitt, 1948; Tandon, 1995). Micronutrient accumulation, uptake, ratios and nutrient use efficiency (NUE) computed, indicated that AS-471 and PAC-6753 were relatively more efficient sunflower hybrids in utilizing bio available micronutrients than the other hybrids and checks. Among different locations, the maximum seed yield produced at Coimbatore might be due to the balanced uptake and utilization of micronutrients *vis-a-vis* their availability in soil.

Table 2 **Micronutrient use efficiency (g/kg) and uptake ratio of sunflower seeds**

	Nutrient use efficiency (g kg^{-1})				Uptake ratio		
	Zn	Fe	Mn	Cu	Zn : Fe	Zn : Mn	Zn : Cu
Hybrid							
AS-440	17.2	59.7	72.4	49.5	3.47	4.21	2.88
KBSH-1	17.8	83.5	62.1	54.4	4.67	3.48	3.05
PAC-6753	15.9	48.5	58.9	49.1	3.05	3.70	3.09
AS-471	15.9	41.8	61.6	47.7	2.62	3.87	2.99
MSFH-17	18.5	47.3	67.9	60.8	2.55	3.67	3.28
AS-468	17.6	53.0	67.3	49.1	3.01	3.82	2.76
PAC-2514	17.1	53.1	64.3	45.5	3.10	3.75	2.66
Location							
Amreli	16.7	51.9	69.5	54.1	3.10	4.16	3.24
Bangalore	23.6	48.9	72.5	78.9	2.07	3.06	3.34
Akola	11.4	70.3	78.0	57.5	6.15	6.82	5.03
Nandyal	13.6	55.5	41.8	50.6	4.08	3.07	3.72
Coimbatore	17.6	65.0	64.0	43.1	3.68	3.62	2.44
Kopargaon	18.7	39.9	61.0	39.2	2.12	3.26	2.09

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Short communication

Integrated nutrient management in sunflower, *Helianthus annuus* L. production

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Fertilizer is the major input through which the productivity of sunflower can be increased by exploiting varietal potential. Chemical fertilizers have had a substantial impact on yield increments in the recent past, and are today an indispensable part of modern agriculture. Chemical fertilizers are commonly used for the supply of major plant nutrients, whereas organic manures supply both micro and macro nutrients. Biofertilizers have a supplementary and complementary nutritive role in productivity, but can not replace chemical fertilizers for any major crop, but can improve soil quality, eco friendly and low cost input. An experiment was therefore planned on integrated nutrient management in sunflower to study the quality characters and economics of production.

A field experiment was conducted on an inceptisols during *rabi* 1997-98 at college farm, S.V. Agricultural College, Tirupati (A.P). The soil of the experimental field was sandy clay loam with 73.4% sand, 4.93% silt and 21.67% clay. The pH and E.C were 7.7 and 0.23 ds m^{-1} respectively. The experiment was laid out in a randomised block design with three replications (Table 1).

The bioagrorich compost 1.23, 0.97 and 1.27 % NPK was obtained from Karnataka compost development corporation Ltd; Bangalore and FYM 0.75, 0.30 and 0.75 % NPK was procured from college farm yard. *Azospirillum* and *Azotobacter* were applied to the soil at the rate of 2 Kg/ha. Nitrogen was applied in the form of urea, phosphorous and potassium were applied in the form of single super phosphate (SSP) and muriate of potash (MOP) respectively. Entire dose of SSP, MOP and half the dose of urea was applied at sowing and the other half of urea was applied at 30 days after sowing.

The diameter of head of five plants from each plot was measured at harvest. For test weight thousand seeds were taken from each plot. From the net plot area seed yield was recorded and then calculated for hectare. The data presented was subjected to statistical analysis following the analysis of variance for randomised block design.

Yield : The data on seed yield revealed that highest and significant yield was recorded with soil application of *Azotobacter* along with recommended dose of 80:40:30 NPK/ha, followed by soil application of *Azospirillum* and recommended dose of nutrients (Table 1). The increase in yield in these treatments might be due to the positive influence on yield attributing factors such as head diameter, number of seeds per head and test weight. Similar results were obtained by Amruthavalli (1993), Palazzo *et. al.* (1997); Singaravel *et. al.* (1998).

Oil content : Perusal of the data revealed that oil content ranged from 43.78 to 37.16 with a mean of 40.30%. Highest oil content was recorded in control (43.78). There was no significant variation in oil content between the treatments of control and application of bioagrorich compost @ 6 t/ha. However these treatments significantly enhanced oil content compared to the other combinations. The least oil content has been in T_2 (37.16%), which was comparable with T_9 and T_{11} with oil contents of 37.22 and 37.41 %, respectively (Table 1). Oil yield ranged from 662.16 to 380.73 with a mean of 561.63 Kg/ha. Significantly more oil yield was recorded in T_{11} (662.16) and least in control, (380.73 kg/ha).

Protein (%) : Protein content was significantly higher in T_{11} (13.87) and T_9 (13.83), which were at par (Table 1). These treatments were supplied with biofertilizers along with recommended dose of NPK. Higher protein content was due to high nitrogen content in seed in these treatments which was due to partial nitrogen supplementation by bacterial fixation along with inorganic N P and K. It might also be attributed to the more stimulation given by biofertilizers in increased uptake of nitrogen. Amruthavalli (1993) also obtained similar results.

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Economics : Since different fertilizers were applied in different quantities the cost of fertilization for each treatment varied. As T_9 and T_{11} received recommended dose of chemical fertilizers i.e., NPK and biofertilizers, the cost of fertilization was maximum. From the table 2 it is clear that the cost of cultivation was minimum for control (Rs. 7360),equal and maximum in T_9 and T_{11} (Rs. 9419).

Table 1 Seed yield and quality characters of sunflower as influenced by Integrated Nutrient Management

	Treatment	Seed yield (q/ha)	Oil content (%)	Oil yield (kg/ha)	Protein content (%)
T_1	Control	8.69	43.78	380.6	12.99
T_2	*Recommended NPK*	*16.69*	*37.16*	*620.3*	*13.06*
T_3	FYM @ 12t/ha	10.67	43.06	459.7	12.97
T_4	FYM 25% + Inorganic recommended 75% N	16.17	38.21	617.8	11.66
T_5	FYM 50% + Inorganic recommended 50% N	13.78	40.98	564.8	13.41
T_6	Bioagrorich @ 6t/ha	10.48	43.24	453.4	13.22
T_7	Bioagrorich 25% + *Inorganic recommended* 75% N	16.49	38.64	637.4	12.18
T_8	Bioagrogich 50% + Inorganic recommended 50% N	14.15	41.21	583.4	12.62
T_9	*Azospirillum* soil application + 100% N + recommended PK	17.35	37.22	645.7	13.83
T_{10}	*Azospirillum* soil application + 50% N + recommended PK	12.95	41.96	543.7	13.51
T_{11}	Azotobacter soil application + 100% N + recommended PK	17.70	37.41	662.2	13.87
T_{12}	*Azotobacter* soil application + 50% N + recommended PK	13.71	41.60	570.3	13.05
	Mean	14.06	40.37	561.6	13.03
	S.Em±	0.03	0.21	3.00	0.08
	CD (0.05)	0.10	0.63	8.82	0.25

Table 2 Economics in sunflower as influenced by integrated nutrient management

	Treatment	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha-1)	Net returns per *rupee invested*
T_1	Control	7360	9428	2068	0.28
T_2	*Recommended NPK*	9404	20028	10224	1.08
T_3	FYM @ 12t/ha	8760	12804	3994	0.45
T_4	FYM 25% + Inorganic recommended 75% N	8343	19404	11011	1.31
T_5	FYM 50% + Inorganic recommended 50% N	8482	16536	8004	0.94
T_6	Bioagrorich @ 6t/ha	9060	12576	3516	0.38
T_7	*Bioagrorich* 25% + Inorganic recommended 75% N	8418	19788	11370	1.35
T_8	Bioagrogich 50% + Inorganic recommended 50% N	8632	16980	8348	0.96
T_9	*Azospirillum* soil application + 100% N + recommended PK	9419	22820	13701	1.50
T_{10}	*Azospirillum* soil application + 50% N + *recommended PK*	9097	15540	6043	0.66
T_{11}	Azotobacter soil application + 100% N + recommended PK	9419	23240	14121	1.54
T_{12}	*Azotobacter* soil application + 50% N + recommended PK	9097	16452	6955	0.76

Cost of cultivation included (land preparation, seeding and sowing, weeding, fertilizers, irrigation, harvesting, threshing, bird scaring, etc.)

Economic evaluation in terms of gross returns and net returns showed that the T_{11} (*Azotobacter* soil application + Recommended NPK) gave higher gross returns as well as net returns of Rs. 23240 and Rs. 14121 respectively. T_9 (Azospirillum soil application + recommended NPK) is also on par with T_{11} where the gross returns and net returns were Rs. 22820 and Rs. 13701 respectively (Table 2). These returns were significantly superior to control, where the gross returns and net returns were Rs. 9428 and Rs. 2068. Net return per rupee invested was least in T_1 (0.28), maximum and comparable in T_{11} (*Azotobacter* soil application + Recommended NPK) (1.54) and T_9 (*Azospirillum* soil application + Recommended NPK) (1.50). It can be inferred that application of recommended dose of inorganic fertilizers along with biofertilizers either *Azospirillum* or *Azotobacter* proved to be more remunerative.

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Short communication

Effect of crop geometry on growth and yield of rainfed spanish bunch groundnut varieties

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The spatial arrangement of plants facilitates better utilization of resources and intercultural operations. Sambasiva Reddy *et al.* (1983) reported that the pod and haulm yield of virginia runner groundnut (Kadiri I) did not differ significantly between geometries of 45 x 8.3 cm and 60 x 6.3 cm at Kadiri. Hence, the present study was initiated to find out suitable crop geometry for rainfed spanish bunch groundnut varieties.

A field experiment was conducted at Tirupati campus of Acharya N.G. Ranga Agricultural University under rainfed conditions. The soil of the experimental field was sandy loam with pH 5.2, organic carbon 0.15% and available P and K of 28 and 165 kg/ha respectively. Twenty four treatments comprising, combinations of three varieties (TMV 2, JL 24 and Tirupati 2) and eight crop geometries were tested in randomised block design with factorial concept and replicated thrice (Table 1). A fertilizer dose of 20 N + 40 P_2O_5 kg/ha was applied basally. The amount of rainfall received during the crop period (468.1 mm in 29 rainy days) was less by 21.5 % than the decennial average (596.6 mm in 28 rainy days). However, the distribution of rainfall was quite favourable for crop growth.

Taller plants were with TMV 2. Plant height of JL 24 and Tirupati 2 did not differ significantly (Table 1). Inter-row plant spread, LAI at 75 DAS, total dry matter at maturity and 100 kernel weight were higher with JL 24 whereas total pods per plant were higher with TMV 2. Intra-row plant spread did not vary significantly due to varieties. Pod and haulm yield of JL 24 was more followed by TMV 2 and Tirupati 2.

Plant height with a geometry of 60 x 5 cm was higher which was comparable to 52.5 x 5.7 cm and 45 x 6.7 cm irrespective of varieties. Inter and Intra-row plant spread was higher with 60 x 5 cm and 15 x 15 cm, respectively. Intra-row plant spread obtained with 15 x 15 cm was on par with 17.3 x 17.3 cm. LAI at 75 days after sowing and total dry matter production at maturity were higher with a crop geometry of 30 x 10 cm. Total pods per plant and shelling percentage were higher with a crop geometry of 30 x 10 cm. The 100 kernel weight was higher with 60 x 5 cm which was comparable with 52.5 x 5.7 cm, 45 x 6.7 cm, 37.5 x 8 cm and 30 x 10 cm. Pod and haulm yield was higher with a crop geometry of 30 x 10 cm. Similar variation in yield with change of crop geometry was also observed by Usha Rani (1983).

Interaction between varieties and crop geometry (Table 2) revealed the maximum pod yield of 2438 kg/ha was obtained with JL 24 at a geometry of 30 x 10 cm but it was comparable with the same variety at a geometry of 60 x 5 cm. Haulm yield followed similar trend as that of pod yield.

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Table 1 Effect of crop geometry on growth and yield of rainfed spanish bunch groundnut varieties

Treatment	Plant height (cm)	Plant spread (cm)		LAI at 75 DAS	Total dry matter at maturity (g/m^2)	Total pods/plant	100 kernel weight (g)	Shelling percentage	Yield (kg/ha)	
		Inter row	Intra row						Pod	Haulm
Variety										
JL 24	37.0	46.5	32.6	2.90	503.1	11.5	48.1	71.6	2251	3002
TMV 2	43.9	44.5	32.5	2.77	450.1	12.7	33.3	69.2	1983	2644
Tirupati 2	34.9	41.7	31.8	2.50	421.9	11.6	31.5	71.1	1792	2422
S.Em±	0.8	0.5	0.4	0.04	1.6	0.2	0.3	0.2	15	19
C.D (0.05)	2.2	1.3	NS	0.11	4.5	0.4	1.0	0.6	41	52
Crop geometry										
15.0 x 15.0 cm	35.8	35.5	36.7	2.78	441.6	11.2	35.7	67.9	1877	2602
17.3 x 17.3 cm	34.6	37.7	35.6	2.89	465.1	11.5	36.4	69.3	2044	2722
22.5 x 13.3 cm	36.9	40.1	34.6	2.99	489.2	12.6	36.8	70.5	2086	2773
30.0 x 10.0 cm	38.1	42.4	33.5	3.24	516.5	13.6	37.9	72.5	2144	2859
37.5 x 8.0 cm	38.7	45.5	32.0	2.66	463.7	12.8	38.3	71.3	2046	2728
45.0 x 6.7 cm	40.1	48.0	30.4	2.52	442.8	11.5	38.3	71.0	2009	2679
52.5 x 5.7 cm	41.6	50.9	28.5	2.40	424.1	11.3	38.6	70.0	1898	2531
60.0 x 5.0 cm	42.9	53.8	26.9	2.31	423.8	10.6	39.0	72.3	1968	2621
S.Em±	1.3	0.8	0.7	0.06	2.7	0.3	0.6	0.4	24	31
C.D (0.05)	3.6	2.1	2.0	0.17	7.4	0.7	1.6	1.0	67	86

DAS : Days after sowing

Table 2 Interaction between varieties and crop geometry on pod and haulm yield of groundnut

Crop geometry	Pod yield (kg/ha)			Haulm yield (kg/ha)		
	Variety					
	JL 24	TMV 2	*Tirupati 2*	JL 24	TMV 2	*Tirupati 2*
15.0 x 15.0 cm	1926	1882	1822	2686	2611	2510
17.3 x 17.3 cm	2200	2105	1826	2842	2794	2530
22.5 x 13.3 cm	2297	2115	1847	3035	2771	2513
30.0 x 10.0 cm	2438	2122	1871	3251	2795	2531
37.5 x 8.0 cm	2264	2028	1846	3019	2704	2461
45.0 x 6.7 cm	2260	1964	1803	3013	2619	2404
52.5 x 5.7 cm	2255	1807	1633	3007	2409	2177
60.0 x 5.0 cm	2370	1840	1687	3161	2453	2249
S.Em±		42			54	
C.D (0.05)		116			149	

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Short communication

Response of sesame (*Sesamum indicum* L.) to manganese and zinc nutrition

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Sesame, though occupies larger area of 2.5 m ha in our country, a low yield of only about 180 kg ha^{-1} is produced. Since not many varieties of high yield potentials are available, it has become necessary to look into the other aspects of production technology, particularly fertilization, in order to increase the production level. Application of micronutrients would be beneficial since response is obtained to a greater extent owing to wide spread micronutrient deficiencies. Hence, the present study was undertaken to assess the effect of application of zinc and manganese on sesame.

A pot culture experiment was conducted at the Annamalai University during summer (Feb - April, 1999) to study the response of sesame to Zn and Mn application. The soil used for the experiment was clay with pH 7.55 and EC 0.34 dS m^{-1}. It was low in available N (220 kg ha^{-1}), medium in available P (19 kg ha^{-1}) and potassium (214 kg ha^{-1}). The DTPA extractable Zn (90.9 ppm) and Mn (0.7 ppm) were below the critical limits. The experiment was laid out in completely randomized design with eight treatments and three replications using sesame variety TMV 3 (Table 1).

A fertilizer dose of 35:22.5:22.5 N, P_2O_5 and K_2O kg ha^{-1} was applied basally to all the pots through urea, single super phosphate and muriate of potash, respectively. The micronutrients were applied in soil to the concerned pots before sowing. Foliar application of Zn and Mn was done on 25th and 45th day after sowing (DAS). The data on the growth and yield of sesame was recorded. In the di-acid extract of the plant samples, various nutrient contents were estimated using standard procedure (Jackson, 1973) and their uptake was computed.

Growth

The results showed that application of micronutrients either as soil or foliar resulted in increased plant growth characters of sesame. Soil application of $ZnSO_4$ and $MnSO_4$ recorded the highest plant height (105 cm) and dry matter production (DMP) of 2805 kg ha^{-1} as compared to 70 cm and 1860 kg ha^{-1} respectively in control representing 50.0 and 50.81 % increase over control. The individual application of Zn and Mn in soil produced a plant height of 78 cm and 92 cm and DMP of 2100 Kg ha^{-1} and 2420 Kg ha^{-1} respectively. The increased plant growth characters with application of micronutrient were reported by Tiwari *et al.*, (1995).

Table 1 Influence of micronutrient treatments on growth, yield components and yield of sesame

Treatment	Plant height (cm)	Dry matter (kg ha^{-1})	No. of capsules/ plant	No. of seeds/ capsule	100 seed weight (g)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
T_1 - Rec. NPK (35:22.5:22.5)	70	1860	30	32.3	2.56	540	1223
T_2 - NPK + $ZnSO_4$ 25 kg/ha (soil)	78	2100	38	38.3	2.86	592	1375
T_3 - NPK + $MnSO_4$ 5 kg/ha (soil)	92	2420	50	48.0	2.68	684	1828
T_4 - NPK + 0.5% $ZnSO_4$ (foliar)	90	2320	47	44.1	2.78	611	1705
T_5 - NPK + 0.5% $MnSO_4$ (foliar)	81	2180	41	40.0	2.92	602	1505
T_6 - NPK + $ZnSO_4$ 25 kg/ha + $MnSO_4$ 5 kg/ha (soil)	105	2805	59	57.0	3.04	794	2299
T_7 - NPK + 0.5% $ZnSO_4$ + 0.5% $MnSO_4$ (foliar)	99	2780	56	52.0	3.00	749	2111
SEm±	1.15	61.73	1.27	1.82	0.026	11.38	23.68
CD (0.05)	2.50	134.51	2.77	3.66	0.056	24.80	51.65

Table 2 Influence of micronutrient treatments on the nutrient uptake of sesame

Treatment	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		Zn (kg ha^{-1})		Mn (kg ha^{-1})		Fe (kg ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	13.96	8.84	21.62	1.85	31.39	22.10	0.017	0.044	0.032	0.31	0.033	0.31
T_2	17.27	13.16	30.10	2.65	35.25	25.64	0.025	0.070	0.038	0.45	0.038	0.45
T_3	21.48	31.33	40.19	4.10	44.73	36.64	0.024	0.073	0.051	0.68	0.048	0.68
T_4	18.93	24.96	34.46	3.78	38.71	33.38	0.025	0.076	0.039	0.58	0.043	0.58
T_5	17.87	18.27	32.96	3.22	36.72	29.03	0.023	0.063	0.043	0.53	0.040	0.53
T_6	25.77	46.11	51.18	5.88	53.01	47.46	0.036	0.121	0.064	0.92	0.060	0.92
T_7	23.62	38.95	45.84	5.31	50.28	43.09	0.031	0.100	0.057	0.81	0.050	0.81
SEm±	0.59	3.02	4.93	0.87	0.95	0.95	0.001	0.003	0.012	0.029	0.001	0.029
C.D(0.05)	1.29	6.57	10.74	1.91	2.08	2.08	0.002	0.007	0.004	0.060	0.002	0.060

Yield components and yield

Application of either Zn or Mn alone or in combination has resulted in increased yield components viz., capsules per plant and seeds per capsule. The combined application of Zn and Mn in soil had produced the highest capsules per plant (59) and seeds per capsule (57). The beneficial influence of micronutrients on the yield components of sesame might be due to activation of various enzymes and efficient utilisation of applied nutrients, especially nitrogen and phosphorus, resulting in increased yield components as reported by Tiwari *et al.* (1995) and Shanker *et al.* (1999).

The highest seed and stalk yield of 794 and 2299 kg ha^{-1} was recorded with the treatment, (soil application of Zn + Mn) in comparison to 540 and 1223 kg ha^{-1} in control. This represented a percentage increase of 47 and 53 over control. The application of Zn alone as foliar and soil increased the yield in the range of 592 to 611 Kg ha^{-1} and Mn alone in the range of 602 to 684 Kg ha^{-1}. The combined application recorded a yield range of 749 to 794 Kg ha^{-1}. The positive response of sesame to Zn and Mn application over control was due to increased growth and yield components produced and increased availability and better uptake of these nutrients. The present results are in conformity with the earlier findings of Vadivel (1980) and Balamurugan (1982).

Nutrient uptake

The combined application of Zn + Mn (soil) registered the highest NPK uptake in seed and stalk. The increased uptake might have been the result of increased DMP produced. There was also significant increase in micronutrient uptake due to application of Zn and Mn (*Table 2*). The treatment, soil application of Zn+Mn resulted in increased uptake of Fe, Mn and Zn in seed to the tune of 0.06, 0.064 and 0.036 kg ha^{-1} and 0.72, 0.92 and 0.121 kg ha^{-1} in shoot as compared to 0.033, 0.032 and 0.017 kg ha^{-1} in seed and 0.26, 0.31 and 0.044 in stalk in control.

A marked improvement in the availability with higher absorption resulted in higher uptake of these nutrients. Increased uptake of micronutrients with the Zn and Mn has been well documented (Vadivel, 1980., Balamurugan, 1982).

The present study clearly indicated that for increasing the productivity of sesame,, application of recommended dose of NPK along with $ZnSO_4$ @ 25 kg ha^{-1} + MnSO4 @ 5 Kg ha^{-1} to soil would be beneficial.

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Short communication

Comparative virulence of isolates of *Aspergillus niger* van Teighem causing seed rot and collar rot of groundnut in different seasons

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Seed rot and collar rot disease of groundnut caused by *Aspergillus niger* van Teighem is a destructive disease and cause upto 50% loss in yield (Chahal *et al.*, 1974). In extreme cases this pathogen can attack pegs, shells and kernels of groundnut cultivars (Peittit *et al.*, 1989). The present study was taken up to evaluate infectivity potential of different isolates causing seed and collar rot disease in different seasons under green house condition.

The experiment was conducted in green house during rainy, winter and summer seasons of 1992-1994 in the Department of Plant Pathology, B.C.K.V., Kalyani (WB). Nine isolates (S_2, S_3, S_5, S_{16}, S_{18}, S_{20}, S_{21}, S_{22}, S_{23}) of *Aspergillus niger* collected from the soils of cultivated field from four agroclimatic zones of West Bengal, using modified martins dextrose peptone rose Bengal agar medium. Another isolate (S_{24}) was isolated from infected seeds of groundnut. The fungal isolates were got identified from Division of Mycology and Plant Pathology, IARI, New Delhi and maintained on freshly prepared PDA medium. Mass culturing of each isolate was done on sand maize meal medium in Poly Propylene Packets (25 x 10 cm^2) and incubated at 28 ± 1°C for 10 days. Each isolate was then mixed throughly with upper 8 cm double sterilized soil (1:3 v/v) of different plastic pots (20 cm). These pots were kept in a green house for 7 days and the moisture level was maintained by watering every alternate days.

Ten surface sterilized groundnut seeds of cv. JL - 24 (0.1%$HgCl_2$ solution for 1 min.) were sown in each inoculated pot, kept randomly following a complete randomized block design Watering was done as and when required. After 7 days, seeds were taken out carefully from the infected soil and percent of rotted seeds was computed. For collar rot infection study, 10 day old seedlings were inoculated with the isolates at the collar region following soil inoculation technique. Relative disease incidence was recorded in percent basis after 30 days of inoculation. The experiment was conducted in three different seasons viz. rainy, winter and summer season in two consecutive years (1992 - '93 and 1993 - '94). Seeds were sown on 3rd May, 1st October and 2nd February for rainy, winter and summer season, respectively.

Relative pathogenicity of different isolates was assessed by using the method mentioned earlier for two consecutive years and one uninoculated pot where surface sterilized seeds were sown was treated as control. The seeds were sown on 1st June, 2nd October, 2nd February and 2nd May. Three replications were maintained and percent disease incidence was recorded to assess the pathogenicity of different isolates.

All the isolates were significantly different in seed rotting in different seasons except uninoculated control (Table 1). Maximum seed rot incidence was observed in summer and minimum in rainy season. This trend was showed in every isolate for two consecutive years. Among the isolates S_{16} caused maximum seed rotting (42.5%) in summer followed by S_{21} (37.5%). No significant difference in seed rotting was observed in case of S_2, S_3, S_5, S_{22}, S_{23} and S_{24} treated pots and S_2, S_{18}, S_{20}, S_{22} isolates also. In winter no significant difference was observed among the isolates of S_2, S_3, S_5, S_{18}, S_{20}, S_{21} and S_{22} in seed rotting though maximum rotting was observed on S_{16} (37.5%) and minimum on S_{22} (22.5%). Similar trend was observed in rainy season also.

In case of persistency of virulence, it was observed that S_{24} caused maximum seed rot followed by S_{16} and S_3. No significant difference was observed between the isolates of S_2, S_5, S_{23} and S_{18} in extent of seed rotting. Gradually seed rot was reduced significantly when the seeds were sown in the month of October then February and least in May. This trend was observed for two consecutive years in every isolate (Table 2).

Table 1 Relative incidence of seed and collar rot disease of groundnut in different cropping seasons

Isolate	Season	Disease incidence (%)	
		Seed rot	Collar rot
S_2	Rainy	25.0 (30.21)	40.0 (39.33)
	Winter	27.5 (31.66)	17.5 (24.83)
	Summer	32.5 (34.86)	22.5 (28.42)
S_3	Rainy	27.5 (31.68)	40.0 (39.39)
	Winter	30.0 (33.30)	17.5 (24.84)
	Summer	35.0 (36.29)	17.5 (24.85)
S_5	Rainy	20.0 (26.59)	37.5 (37.79)
	Winter	30.0 (33.25)	20.0 (26.58)
	Summer	35.0 (36.33)	12.5 (20.73)
S_{16}	Rainy	30.0 (33.28)	37.5 (37.77)
	Winter	37.5 (37.79)	22.5 (28.36)
	Summer	42.5 (40.71)	12.5 (20.72)
S_{18}	Rainy	15.0 (22.79)	37.5 (37.77)
	Winter	30.0 (33.24)	20.0 (26.58)
	Summer	30.0 (33.24)	12.5 (20.72)
S_{20}	Rainy	17.5 (24.76)	32.5 (34.78)
	Winter	27.0 (31.20)	22.5 (26.34)
	Summer	30.0 (33.26)	12.5 (20.72)
S_{21}	Rainy	20.0 (26.58)	37.5 (37.78)
	Winter	27.5 (31.64)	25.0 (30.10)
	Summer	37.5 (37.78)	17.5 (24.74)
S_{22}	Rainy	17.5 (24.74)	32.5 (34.78)
	Winter	27.5 (31.64)	20.0 (26.58)
	Summer	32.5 (34.77)	17.5 (24.75)
S_{23}	Rainy	12.5 (20.72)	35.0 (36.29)
	Winter	22.5 (26.34)	20.0 (20.58)
	Summer	35.0 (36.28)	10.0 (18.44)
S_{24}	Rainy	25.0 (30.06)	42.5 (40.70)
	Winter	32.5 (34.78)	30.0 (33.24)
	Summer	35.0 (36.28)	25.0 (30.04)
Control (uninoculated)	Rainy	2.08 (8.30)	2.08 (8.32)
	Winter	4.10 (11.69)	0.0 (0.0)
	Summer	4.10 (11.70)	0.0 (0.0)
CD (0.05)			
Isolate		6.32	5.44
Season		3.38	2.84
Interaction		10.97	9.45

Figures in the parenthesis are average angular transformed values.

In case of collar rot, maximum disease was observed during rainy season on isolate S_{24} (42.5%) inoculated pots and no significant difference was observed among S_2, S_3 isolates. The minimum collar rot disease incidence was observed in S_3 isolate in summer season (10 %). In winter season maximum disease was observed in isolate S_{24} (30%) inoculated pots followed by isolate S_{21} (25.0%) which differed significantly among themselves. No significant difference in collar rot disease was observed among the isolates S_{22}, S_{23}, S_{16} and S_{20} inoculated pots. Seasonal variation had a great influence in disease development between the isolates (Table 1).

In case of persistency of virulence of the pathogen causing collar rot it was observed that isolate S_{24} caused maximum collar rot incidence (37.5%) followed by isolates S_{18}, S_5, S_{16}, S_{22} inoculated pots when the seeds were sown in June. Their persistence of virulence was drastically reduced in May sown pots. The maximum reduction of virulence was observed in isolates S_{18}, S_2 and S_5 where no disease was observed when sown in May. The isolates S_3, S_{20}, S_{21}, S_{23} and S_{22} showed minimum disease incidence (2.5 to 5.0%) and were at par. The reduction of virulence significantly differed with time of sowing though the interaction of time and isolates was not significant.

It was observed that isolate S_{16} and S_{24} were more virulent than the other isolates of *A.niger*. All the isolates gradually lost their infectivity within 12 months period. Seed rot was more in summer, less in rainy season, whereas collar rot was more in rainy and least in summer season. Virulence of isolates can be arranged in a descending order as $S_{24}>S_{16}>S_3>S_{18}>S_5>S_{22}>S_2>S_{23}>S_{21}>S_{20}$. Ashworth *et al.*, (1964) reported that delay in emergence of seedling increased seed rot and quicker emergence decreased seed rotting, but collar rot incidence increased in rainy season because the pathogen remains active at high temperature and moisture. Growth and activity of *A.niger* was influenced in warm humid climate and in porus soil.

Chohan (1967) observed that survival of *A. niger* was dependent on relative humidity, though it lost its growth activity at 100% relative humidity after two months of storage. In sterilized soil, it remained viable up to nine months at different levels of soil moisture.

Table 2 **Relative pathogenicity of various isolates of *A. niger* the causal agent of seed and collar rot disease of groundnut and persistence of *infectivity of the sick soil under green house condition***

Treatment		Disease incidence (%)				CD
		June	October	February	May	(0.05)
	S_{2}	20.8 (27.13)	16.7 (24.12)	10.4(18.81)	2.5 (9.1)	For isolates =
	S_{3}	31.3 (34.02)	22.9 (28.59)	6.2 (14.42)	2.5 (9.1)	5.13
	S_{5}	20.8 (27.13)	25.0 (30)	6.2 (14.42)	0 (0)	For months
	S_{16}	35.4 (36.51)	27.1 (31.37)	14.9 (22.71)	14.6 (22.46)	3.23
	S_{18}	18.8 (25.7)	14.58 (22.44)	14.9 (22.71)	10.0 (18.43)	For interaction =
Seed rot	S_{20}	25.0 (30.0)	10.4 (17.85)	6.3 (14.54)	2.5 (9.1)	10.24
	S_{21}	22.9 (29.27)	16.7 (24.12)	4.2 (11.83)	0 (0)	
	S_{22}	20.83 (27.15)	18.8 (25.7)	8.4 (16.55)	0 (0)	
	S_{23}	20.8 (27.13)	12.5 (20.7)	10.4 (18.81)	7.5 (15.89)	
	S_{24}	37.5 (37.76)	31.3 (34.02)	16.7 (24.12)	12.5 (20.7)	
	Control	0 (0)	4.1 (11.54)	2.0 (8.13)	0.1 (1.81)	
	S_{2}	29.7 (33.02)	8.3 (16.74)	4.1(11.68)	0 (0)	For isolates =
	S_{3}	25.4 (30.26)	14.6 (22.46)	6.2 (14.42)	2.5 (9.1)	5.44
	S_{5}	33.3 (35.24)	18.8 (25.7)	6.2 (14.42)	0.0 (0)	For months
	S_{16}	33.3 (35.24)	20.8 (27.13)	16.7 (24.12)	10.41 (18.61)	3.45
	S_{18}	35.4 (36.51)	12.5 (20.7)	8.4 (16.85)	0 (0)	For interaction =
Collar rot	S_{20}	25.0 (30.0)	10.4 (18.81)	8.4 (16.85)	2.5 (9.1)	10.88
	S_{21}	27.1 (31.37)	12.6 (20.79)	8.4 (16.85)	2.5 (9.1)	
	S_{22}	31.3 (34.02)	16.7 (24.12)	6.3 (14.54)	5.0 (12.92)	
	S_{23}	29.2 (32.71)	14.6 (22.46)	10.4 (18.81)	2.5 (9.1)	
	S_{24}	37.5 (37.76)	16.7 (24.12)	18.8 (25.7)	14.6 (22.46)	
	Control	0 (0)	2.0 (8.13)	2.0 (8.13)	0 (0)	

Values in parenthesis are average angular transformed values

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Short communication

Effect of indigenous plant extracts against shoot webber and capsule borer, *Antigastra catalaunalis* Dup. in sesame

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In India, sesame crop is attacked by more than 30 species of pests, of which shoot webber and capsule borer, *Antigastra catalaunalis* Dup. is an important pest causing economic yield loss (Singh *et al.*, 1985). It is an important limiting factor for successful cultivation of sesame in Tamil Nadu. The yield loss due to *A. catalaunalis* was estimated to be 10-60 % (Singh *et al.*, 1985 ; Murali Baskaran *et al.*, 1990). Presently, there is over reliance on insecticides for the control of this pest. Thus, present study was conducted to find out an effective indigenous plant extract for the control of sesame shoot borer.

Field trials were conducted for five seasons during *kharif* 95, summer 96, *kharif* 96, summer 97 and *kharif* 97 at National Pulses Research Centre, Vamban, Pudukkottai district, Tamil Nadu to assess the efficacy of different indigenous plant extracts in controlling the sesame shoot webber and capsule borer. The trials were conducted under irrigated conditions using the local variety TMV 3 in randomized block design with three replications. The treatments consisted of seven indigenous plant extracts, one insecticide namely endosulfan 0.07% as a standard check and a control (Table 1).

Table 1 Effect of indigenous plant extracts in controlling sesame shoot webber

Treatment	Per cent infested plants						reduction over control (%)
	Kharif 1995	Summer 1996	*Kharif* 1996	Summer 1997	*Kharif* 1997	Mean	
Vitex negundo	28.4	29.4	28.9	23.4	24.0	26.6	56.4
leaf extract 5%	(32.2)	(32.8)	(32.5)	(28.9)	(21.4)	(31.0)	
Parthenium hysterophorus	32.2	31.3	32.0	26.2	26.5	28.6	53.0
leaf extract 5%	(33.4)	(34.0)	(34.3)	(30.8)	(31.0)	(32.3)	
Acorus calamus	32.1	31.5	30.1	27.9	27.0	29.2	52.1
rhizome extract 5%	(34.5)	(34.2)	(34.5)	(31.4)	(31.3)	(32.7)	
Eucalyptus terreticornis	31.3	33.8	34.0	27.3	27.2	30.1	50.5
leaf extract 5%	(34.0)	(35.5)	(35.7)	(31.5)	(31.4)	(33.2)	
Datura metal	28.4	30.6	31.7	25.7	26.7	28.3	53.6
leaf extract 5%	(32.2)	(33.6)	(34.2)	(30.5)	(31.1)	(32.1)	
Calotropis gigantea	30.7	33.1	32.8	27.1	26.7	29.4	51.7
leaf extract 5%	(33.6)	(35.1)	(34.9)	(31.3)	(31.1)	(32.8)	
Aristolochia brochiura	30.2	33.0	35.1	27.8	28.2	30.0	50.1
leaf extract 5%	(33.3)	(35.0)	(36.3)	(31.8)	(32.1)	(33.2)	
Endosulfan 0.07% (check)	26.4	27.4	27.2	21.4	21.6	24.3	60.0
	(30.9)	(31.5)	(31.5)	(28.0)	(27.9)	29.5)	
Control	65.2	64.2	67.2	52.8	53.3	60.9	
	(59.8)	(53.3)	(55.5)	(46.6)	(46.9)	(51.4)	

Figures in parentheses are arc sin transformed means

Level of significance	SEm±	CD (0.05)
Treatments	0.44	1.02
Seasons	0.33	0.72
Treatments X Seasons	1.38	NS

The selected plant material was ground into a paste by using grinder few hours prior to spraying. Required quantity of water was taken and mixed with teepol (1ml/lit) and then the plant extract (paste) was mixed thoroughly with water and filtered through muslin cloth and the volume made up to the required concentration. The plant extracts thus prepared were sprayed thrice at 30, 45 and 60 DAS using hand operated knapsack sprayer. Total number of plants and infested plants in each plot were observed prior to first spray, 7 and 14 days after each spray. The grain yield was recorded and cost : benefit ratio was worked out.

Significant differences were observed between the indigenous plant extracts for its control. The damage was low in endosulfan 0.07% (21.4-27.4%) during all the seasons. Among the plant extracts, *Vitex negundo* leaf extract 5% recorded significantly low damage in all the seasons (23.4-29.4%). *Datura metal* leaf extract 5% was the next best plant extract and registered low damage in all seasons except *kharif* 1996. Control recorded significantly high damage of 52.8 % in summer 1997 to 67.2% in *kharif* 1996.

Pooled data over the five seasons indicated that *V. negundo* leaf extract (5%) was superior with low *A.catalaunalis* damage (26.6%), while endosulfan (0.07%) and control recorded the least (24.3%) and highest (60.9%) damage, respectively. The results also indicated that all the plant extracts were significantly superior to control (Table 1) recording 50-54 % reduction in damage. Senguttuvan and Dhanakodi (1999) reported that the *Vitex* leaf extract (5%) reduced the leaf miner damage in groundnut by 19.3 %. *Vitex* leaf extract was also effective in controlling *Spodoptera* in groundnut (Sahayaraj and Sekar, 1996) and *Achaea janata* in castor (Muthukrishnan and Ananthagowri, 1994). There was significant difference between the seasons and damage. Interaction between the treatments and seasons was not significant. The grain yield was maximum in endosulfan 0.07% during all seasons with a mean of 509 kg/ha, which was 61.1 % higher than in control (316 kg/ha). Among the plant extracts, *V. negundo* leaf extract (5%) recorded the highest yield (455 kg/ha) followed by *D.metal* leaf extract (5%) (419 kg/ha), which were 44 and 32 % higher than in control. The cost : benefit ratio was high in *V.negundo* leaf extract (1:5.8) and endosulfan (1:44) (Table 2). Significant differences were observed between the seasons for grain yield.

Considering both the effectiveness and cost : benefit ratio, *V. negundo* leaf extract 5% was found to be an effective plant extract for the economic control of sesame shoot webber and capsule borer and a best alternative to insecticides.

Table 2 Effect of indigenous plant extracts on grain yield of sesame

Treatment	Mean grain yield (kg/ha)					Mean yield (kg/ha)	Increase over control (%)	C:B ratio
	Kharif 1995	Summer 1996	*Kharif* 1996	Summer 1997	*Kharif* 1997			
Vitex negundo leaf extract 5%	347	472	400	611	444	455	43.98	5.8
Parthenium hysterophorus leaf extract 5%	325	337	356	536	375	398	25.95	3.4
Acorus calamus rhizome extract 5%	322	347	347	542	389	389	23.10	3.0
Eucalyptus terreticornis leaf extract 5%	319	414	353	500	389	395	25.00	3.3
Datura metal leaf extract 5%	342	417	383	550	394	419	31.96	4.2
Calotropis gigantea leaf extract 5%	319	431	375	528	369	404	27.85	3.7
Aristolochia brochiura leaf extract 5%	292	411	383	536	369	398	25.95	3.4
Endosulfan 0.07% (check)	400	508	431	667	542	509	61.08	4.4
Control	239	331	272	411	328	316		

Level of significance	SEd	CD (0.05)
Treatments	1.67	3.73
Seasons	0.73	1.71
Treatments X Seasons	10.43	NS

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Short communication

Predatory potential of two coccinellids against linseed bud fly (*Dasyneura lini* Barnes)

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Bud fly, *Dasyneura lini* Barnes poses a problem for linseed growers, which plunders up to 88% production of linseed in different parts of the country and even may cause total yield loss in epidemics (Pal *et al.*, 1978; Malik *et al.*, 1998). Natural enemies are the integral part of integrated pest management (IPM) for economically viable and eco-friendly strategies. The coccinellids viz., *Coccinella septempunctata* L. and *Menochilus sexmaculatus* F. are the major predators of bud fly maggots out side the floral buds (Malik, 1997). The predatory potential of different stages of grubs and adults of coccinellids was studied for the maggots of bud fly under laboratory conditions.

Different stages of both the coccinellids and fourth instar maggots of bud fly for the experiment were collected from the linseed cv Neelum in mid February, 1998. The predators were starved for four hours before confining them with prey in glass vials with linseed leaves and healthy floral buds. Seventy five maggots (4^{th} instar) of bud fly were released in individual glass vials containing predators with six replications. Total number of prey consumed by the predators was recorded 24 hours after confinement. Critical differences were calculated on the basis of average prey consumed during two days.

The predation propensity of grubs of both the coccinellids increased with the age of the grubs up to third instar, which decreased in fourth instar. The third instar grub of *C.septempunctata* and *M.sexmaculatus* devoured a maximum of 22.94 and 17.14 maggots/day with the range of 20-27 and 15-20 maggots/day, respectively (Table 1). The female predators of these coccinellids consumed higher number of prey (54.46 maggots/day) than the males (48.58 maggots/day). Average feeding propensity of adults (51.48 maggots/day) was more than the grubs (13.21 maggots/ day).

Table 1 Predation of coccinellids on maggots (No./day) of linseed bud fly

Predator stage		*C. septempunctata*		*M. sexmaculatus*		Total Predation	
		Range	Average	Range	Average	Range	Average
I instar grub		7-10	8.18(2.86)	4-7	5.76(2.40)	4-10	6.92(2.63)
II instar grub		13-15	13.62(3.69)	7-11	9.00(3.00)	7-15	11.15(3.34)
III instar grub		20-27	22.94(4.79)	15-20	17.14(4.14)	15-27	19.98(4.47)
IV instar grub		17-22	18.92(4.35)	12-17	14.74(3.84)	12-22	16.81(4.10)
Male adult		50-59	53.58(7.32)	41-47	43.84(6.62)	41-59	48.58(6.97)
Female adult		57-65	60.53(7.78)	46-52	48.58(6.97)	46-65	54.46(7.38)
Total							
Predation	Grub	7-27	15.39(3.92)	4-20	11.17(3.34)	4-27	13.21(3.63)
	Adult	50-65	57.00(7.55)	41-52	46.17(6.80)	41-65	51.48(7.17)
	Mean		26.31(5.13)		20.16(4.49)		23.14(4.81)
Factor		**SEm±**	**CD (0.05)**				
C.septempunctata		0.07	0.21				
M.sexmaculatus		0.04	0.12				
Interaction		0.10	NS				

Figures in parentheses are square root transformation.

Total predation noticed was 6.92, 11.15, 19.98, 16.81 48.58 and 54.46 maggots/day by I, II, III, IV stages of grub, male and female adults, respectively, and both the predators could consume 23.14 maggots/day in all possibilities. These results revealed that *C. septempunctata* was more voracious feeder (26.31 maggots/ day) than *M. sexmaculatus* (20.16 maggots/ day) of maggots of bud fly and feeding propensity of adult stage was higher than the grubs. The literature is silent regarding the predation on bud fly maggots in linseed under laboratory condition, however Malik (1997) and Singh and Mathur (1997) reported 15 and 60% predation in fields, respectively.

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Short communication

Response of groundnut alley cropped with nitrogen fixing tree species to application of organic and inorganic sources of nitrogen

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Groundnut (*Arachis hypogaea* L.) productivity in India is 870 kg ha^{-1} which is less than the world average of one ton ha^{-1}. The low productivity under rainfed conditions is due to inadequate application of fertilizers and low efficiency of applied fertilizers (Zhang Sisu and Shubo, 1995). To enhance the crop yields it is imperative to integrate the crop with certain nitrogen fixing trees in agroforestry. Siris (*Albizia lebbeck* L. Benth), sisso (*Dalbergia sissoo* Roxb) and subabul (*Leucaena leucocephala* Lam.de Wit) are few NFTs which are capable of fixing atmospheric nitrogen and having high content of nitrogen in the leaves (Sreemannarayana *et al.*, 1994). Hence an attempt was made to assess the efficiency of combined application of organic and inorganic sources of nitrogen to rainfed groundnut alley cropped with three nitrogen fixing tree species.

A field experiment was conducted during *kharif*, 1998 at Student's Farm, College of Agriculture, Rajendranagar, Hyderabad. The experimental site was sandy loam with medium to high organic carbon (0.65-0.80 %) medium in available nitrogen (297-310 kg ha^{-1}), phosphorus (26.60-27.78 kg ha^{-1}) and potassium (167-175 kg ha^{-1}). The experiment was laid out in split-split plot design with three alley cropping systems as main treatments (*Dalbergia sissoo* Roxb, *Leucaena leucocephala* Lam.de Wit and *Albizia lebbeck* L.Benth alley cropping systems), two sub treatments (Green leaf manuring at 5 t ha^{-1} and no green leaf manuring) and three sub-sub treatments (0, 20 and 40 kg N ha^{-1}) with three replications. Gross plot size was 9 x 4 m^2 in *Dalbergia* and 6 x 4 m^2 in *Leucaena* and *Albizia* of alley cropping systems. *Dalbergia* spaced at 3 x 4 m^2 of 8 years and *Leucaena* spaced at 2 x 4 m^2 of 6 years and *Albizia lebbeck* spaced at 2 x 4 m^2 of 4 years were pollarded at an height of 2-3 m, 15 days before sowing groundnut. The pollarded leaf material was separated and applied by opening furrows in respective plots at 5 t ha^{-1} 15 days before sowing of the crop along with recommended dose of single superphosphate with respective leaf material in respective systems. Groundnut was sown on 7th July, 1998 with recommended spacing in all alley cropping systems and harvested on 15th October, 1998. Gypsum was applied at 35 DAS at 500 kg ha^{-1}.

Pod yield of groundnut (Table 1) was influenced by green leaf manuring and nitrogen levels except for alley cropping systems. Green leaf manuring gave more pod yield of 1377 kg ha^{-1} as compared to no green leaf manuring (1091 kg ha^{-1}). *Dalbergia* alley cropped groundnut showed higher pod yield (1387 kg ha^{-1}) with green leaf manuring though pod yields were found equal in all the systems. Reduced EC, bulk density and neutral soil reactions (EC from 0.18 to 0.097 dSm^{-1}, BD from 1.64 to 1.2 and pH from 6.5 to 6.9) and better soil physical conditions might have increased the availability of nutrients to groundnut from applied green leaf material resulting in increased pod yields under green leaf manuring. The results were in accordance with the findings of Palled *et al.*, (1997). Nitrogen at 40 kg ha^{-1} resulted in more pod yield of groundnut (1403 kg ha^{-1}) over N_{20} (1377 kg ha^{-1}) and N_0 (923 kg ha^{-1}). Green leaf manuring along with N_{20} produced higher pod yield of groundnut (1630 kg ha^{-1}) than other combinations. Less yield with N_0 could be due to insufficient supply of nitrogen for optimum growth. Better yields with N_{20} kg ha^{-1} could be attributed to better yield components and less vegetative growth. Neither application of 40 kg N ha^{-1} alone (1320 kg ha^{-1}), nor the combination with green leaf manuring (1486 kg ha^{-1}) showed any improvement in pod yield.

Oil content of groundnut (Table 1) was not influenced significantly by nitrogen levels. Nitrogen at 20 kg ha^{-1} induced higher oil content (40.26%) over N_{40} (40.13%) and N_0 (38.57%). *Dalbergia* alley cropping gave higher net returns (Rs. 15267 ha^{-1}) compared to *Leucaena* (Rs. 14086 ha^{-1}) and *Albizia* (Rs. 12862 ha^{-1}) systems. Green leaf manuring gave more net returns (Rs 15613 ha^{-1}) than no green leaf manure (Rs. 12530 ha^{-1}). Green leaf manure

Table 1 **Pod yield and oil content of groundnut as influenced by alley cropping systems, green leaf manuring and nitrogen levels**

Treatment		Pod yield (kg ha^{-1})				Oil content (%)			
		N_0	N_{20}	N_{40}	Mean	N_0	N_{20}	N_{40}	Mean
Dalbergia alley	Green leaf	1026	1635	1498	1387	39.91	41.19	40.39	40.50
	No green leaf	835	1113	1328	1092	39.24	39.99	40.90	39.80
	Mean	930	1374	1413	1239	39.62	40.59	40.24	40.15
Leucaena alley	Green leaf	1050	1631	1448	1376	39.09	41.63	40.86	40.53
	No green leaf	850	1120	1328	1099	38.44	39.56	39.69	39.23
	Mean	950	1375	1388	1238	38.76	40.59	40.28	39.88
Albizia alley	Green leaf	971	1623	1512	1369	38.64	40.19	39.92	39.59
	No green leaf	804	1141	1304	1083	38.51	38.98	39.84	39.11
	Mean	888	1382	1408	1226	38.57	39.58	39.89	39.35
	Means of N levels	923	1377	1403	1235	38.99	40.26	40.13	39.79
	Means of green leaf	1016	1630	1486	1377	39.21	41.00	40.40	40.20
	No green leaf	830	1124	1320	1091	38.76	39.51	39.87	39.38
		S.Em±	**CD (0.05)**				**S.Em±**	**CD (0.05)**	
Between alley cropping systems (F_1)		19.67	NS				0.60	NS	
Between green leaf manures (F_2)		22.40	54.82				0.45	NS	
Between nitrogen levels (F_3)		19.48	40.22				0.47	0.97	
Between $F_1 \times F_2$		33.76	NS				0.81	NS	
Between $F_1 \times F_3$		33.86	NS				0.89	NS	
Between $F_2 \times F_3$		31.75	71.59				0.70	NS	
Between $F_1 \times F_2 \times F_3$		43.58	NS				1.05	NS	

Table 2 **Net returns and benefit : cost ratio of groundnut as influenced by alley cropping systems, green leaf manuring and nitrogen levels**

Treatment		*Net returns (Rs ha^{-1})*				*Benefit : cost ratio*			
		N_0	N_{20}	N_{40}	Mean	N_0	N_{20}	N_{40}	Mean
Dalbergia alley	Green leaf	11646	20613	18376	16878	1.29	2.25	1.90	1.81
	No green leaf	9970	13969	17025	13655	1.28	1.76	2.09	1.71
	Mean	10808	17291	17701	15267	1.28	2.00	1.99	1.76
Leucaena alley	Green leaf	10842	18390	16447	15559	1.25	2.19	1.82	1.75
	No green leaf	9049	12917	15871	12612	1.20	1.69	2.02	1.64
	Mean	9946	16153	16159	14086	1.22	1.94	1.92	1.69
Albizia alley	Green leaf	8607	18223	16378	14403	1.01	2.20	1.85	1.68
	No green leaf	7308	12189	14467	11321	1.00	1.63	1.89	1.51
	Mean	7958	15206	15423	12862	1.00	1.91	1.87	1.59
	Means of N levels	22339	16217	16428	14072	1.17	1.95	1.92	1.68
	Means of green leaf	10365	19408	17067	15613	1.18	2.21	1.85	1.74
	No green leaf	8776	13025	15788	125330	1.16	1.69	2.00	1.62
		S.Em±	**CD (0.05)**				**S.Em±**	**CD (0.05)**	
Between alley cropping systems (F_1)		295.62	820.65				0.036	0.101	
Between green leaf manures (F_2)		335.56	821.11				0.040	0.100	
Between nitrogen levels (F_3)		293.64	606.07				0.036	0.751	
Between $F_1 \times F_2$		506.25	NS				0.062	NS	
Between $F_1 \times F_3$		509.75	NS				0.063	NS	
Between $F_2 \times F_3$		477.67	1075.0				0.058	0.145	
Between $F_1 \times F_2 \times F_3$		657.78	NS				0.080	NS	

Table 3 **Response function of nitrogen fertility in groundnut as influenced by alley cropping systems, green leaf manuring and nitrogen levels**

Treatment		Observed yield (kg ha^{-1})	Expected yield (kg ha^{-1})	Quadratic equation and optimum level of nitrogen (kg ha^{-1})
DAC	GLM			
	N_0	1026	1026	Y = 1026+49.
	N_{10}		1424	10X+ -0.9325X2
	N_{20}	1635	1635	Optimum N
	N_{30}		1660	level =
	N_{40}	1498	1498	26.02
DAC	NGLM			
	N_0	835	835	Y = 835+78.
	N_{10}		982	09X+ -1.1224X2
	N_{20}	1113	1113	Optimum N
	N_{30}		1227	level =
	N_{40}	1328	1328	34.3
LAC	GLM			
	N_0	1050	1050	Y = 1050+48.
	N_{10}		1436	14X+ -0.9549X2
	N_{20}	1631	1631	Optimum N
	N_{30}		1635	level =
	N_{40}	1448	1448	24.9
LAC	NGLM			
	N_0	850	850	Y = 850+78.
	N_{10}		993	79X+ -1.1399X2
	N_{20}	1120	1120	Optimum N
	N_{30}		1230	level =
	N_{40}	1328	1328	34.31
AAC	GLM			
	N_0	970	970	Y = 970+51.
	N_{10}		1391	61X+ -0.9537X2
	N_{20}	1623	1623	Optimum N
	N_{30}		1662	level =
	N_{40}	1512	1512	26.79
AAC	NGLM			
	N_0	804	804	Y = 804+81.
	N_{10}		1002	50X+ -1.2225X2
	N_{20}	1141	1141	Optimum N
	N_{30}		1237	level =
	N_{40}	1304	1304	33.10

DAC : *Dalbergia* alley cropping; LAC : *Leucaena* alley cropping; AAC : Albizia alley cropping, GLM: Green leaf manuring; NGLM : No green leaf manuring

under *Dalbergia* gave higher net returns (Rs. 16878 ha^{-1}) compared with *Leucaena* (Rs. 15559 ha^{-1}) and *Albizia* (Rs. 14403 ha^{-1}). Similar results were reported by Chavan *et al.*, (1993). Nitrogen at 40 kg ha^{-1} and 20 kg ha^{-1} gave higher net returns of Rs.16428 and 16271 ha^{-1}, respectively over N_0 (Rs.9570 ha^{-1}). Green leaf manuring along with N_{20} recorded higher net returns (Rs. 19408 ha^{-1}) compared to other interaction effects.

Dalbergia alley cropping gave higher BCR (1.76) compared to *Leucaena* (1.69) and *Albizia* (1.59) systems (Table 2). Green leaf manuring produced significantly higher BCR (1.74) as compared to no green leaf manuring (1.62). *Dalbergia* alley cropping with green leaf manuring had higher BCR (1.81) compared to other systems. Nitrogen at 20 kg ha^{-1} gave higher BCR (1.95) as compared to N_{40} (1.92) and N_0 (1.17). Green leaf manuring plus N_{20} resulted in higher BCR (2.21) as *compared to other interaction effects.*

The response of groundnut (Table 3) to applied organic *and inorganic sources of nitrogen was found asymptotic.* The optimum dose of nitrogen observed were 26.02, 24.91 *and 28.79 kg ha^{-1} with green leaf manuring under Dalbergia, Leucaena* and *Albizia* alley cropping systems, respectively. However, without green leaf manuring higher nitrogen was required with values of 35.53, 34.31 and 33.10 kg N ha^{-1} to produce optimum yields under respective systems. The optimum dose of nitrogen found was less by 9.51, 9.4 and 4.31 kg ha^{-1} under these respective alley cropping systems with green leaf manuring when compared to no green leaf manuring. The response clearly indicated that the part of nitrogen to groundnut could be substituted through green leaf manuring under alley cropping systems. Similar results were reported by Endrias (1998).

Findings of the present study revealed that alley cropping of groundnut with nitrogen fixing tree species (NFTs) was found more remunerative. The benefits increased further with application of green leaf manuring of respective NFTs. It was also apparent that about 20 kg N ha^{-1} could be saved to rainfed groundnut with such systems.

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Book Review

GENETIC IMPROVEMENT OF GROUNDNUT

By T. Ramanathan

Associated Publishing Company, New Delhi-110 005
260 pages :: Price Rs.800/- (E-mail : apcbooks.com)

Groundnut, a gift of the "New World" to the "Old World" has assumed the status of the major oilseed crop in India. Notwithstanding its large area in the semi-arid tropics of the world, the crop is termed as 'unpredictable legume'. The complexities of the inter-relationships between the canopy development and the sub-terranean fruiting habit of this legume have intrigued the scientists and farmers alike.

Considering the time lag since the publication of earlier books and monographs on groundnut, there is need for a publication on groundnut improvement encompassing the current status of groundnut improvement and the recent researches carried out. Hence, the book **"Genetic Improvement of Groundnut"** by **Dr. T. Ramanathan** is welcome. The author has accomplished a commendable job in compiling the relevant information on valuable genetic resources for various attributes. The book also contains very useful information on biotechnology and genetic engineering of groundnut. Chapter II deals on breeding for resistance to abiotic stresses, particularly the nutrient deficiency tolerance. Another plus point of the book is the method of evaluation for pest resistance. The author has also presented detailed accounts of drought resistance, breeding for early maturity and fresh seed dormancy and other aspects of groundnut breeding.

Groundnut improvement, however, can not be divorced from other related areas of science *viz.*, groundnut physiology. Without the involvement of the plant physiological parameters, tangible progress in groundnut improvement is not possible. Hence, compilation of the work carried out on the role of plant physiological attributes on groundnut productivity would have enhanced the value of the book. The current groundnut breeding in India needs a clear focus. The past efforts in groundnut breeding suffered for want of precise selection criteria with specific reference to its productivity. Traditional selection criteria for productivity in groundnut based on traditional yield component attributes being highly unstable there is an urgent to re-orient the selection criteria for productivity. Looking at the present state of groundnut improvement in the country, the review of the work carried out on the more stable selection criteria to be employed in groundnut breeding would have been very useful.

The list of the varieties released through hybridization presented on page 70 in Table 8.2 is by no means complete, as some new valuable varieties possessing desirable attributes including drought tolerance, released at the national level in nineties are missing. The author has put more emphasis on the work carried out in Tamil Nadu. The details of genotypes with high oil content (Table 12.1) without corresponding values for the parental and check varieties for comparison, may not be useful. A mention about stem necrosis under bud necrosis of groundnut would have been useful. The details with regard to the sources of disease resistant genotypes would have been very useful. All the while, groundnut has been presented as an oilseed crop. The book of this nature should have discussed the food value of the crop. It may be pertinent to point that groundnut has carved a niche for itself as a significant food crop of the world and the role of groundnut as a food crop is increasing with time.

The book is very neatly bound and presents an impressive get up, but, priced slightly higher. The book is useful to all those engaged in groundnut improvement.

- M.V.R. Prasad
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Directorate of Oilseeds Research, Hyderabad

Short communications

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