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Contents

Research Papers

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Short Communications

J. Oilseeds Res., **24(1)** : 1-11 (2007)

Review Article

Integrated management of *Lipaphis erysimi* (Kaltenbach) in oilseed *Brassica* crops : A review

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Abstract

The mustard aphid, *Lipaphis erysimi* (Kaltenbach) is the key pest of rapeseed mustard crops and damages the crops ranging from 9-96 % in different agro-climatic conditions of India. The existence of glucosinolate-myrosinase system in *L. erysimi* was realized in recent years which is a well defined phytochemical character of crucifers. The temperature between 20-25°C, average rainfall 39 mm, RH 72% and the tender stage of the crop are conducive for the population build up of mustard aphid. The various population count methods and economic threshold levels commonly followed in India have been discussed. Integrated management based on cultural control, development of resistant varieties by conventional breeding and with the help of biotechnological tools, use of botanicals and natural enemies and application of insecticides following economic threshold level is the ideal approach to manage aphid pests in oilseed *Brassica* crops.

Key words: Oilseed *Brassica* crops, *Lipaphis erysimi*, integrated management

Introduction

Rapeseed-mustard accounts for nearly 6 m. ha acerage with a production of about 5.8 m tones of oilseeds in India (Katiyar *et al.*, 2005). Its national average productivity is quite low i.e., 903 kg/ha as against the potential yield of 2600-3000 kg/ha (Sharma, 2005). The production of rapeseed-mustard is low in India as compared to other countries because it is mainly grown in marginal lands under rainfed conditions, low and imbalanced use of fertilizers and of damages due to insect pests and diseases (Bakhetia and Sekhon, 1989). More than 43 species of insect pests infest rapeseed-mustard crops in India, which include about a dozen species as major pests (Purwar *et al.*, 2004). The mustard aphid, *Lipaphis erysimi* (Kaltenback) (Homoptera: Aphididae) is the key pest of rapeseed-mustard and damages the crop ranging from 9 to 96% in different agro-climatic conditions of India (Singh and Sharma, 2002). The pests cause severe damage to the crop in the absence of control measures. The losses in seed yield can be minimized by adopting chemical control measures. However, in addition to the high cost of insecticides, several other drawbacks of the chemical control, *viz.*, development of resistance to commonly used insecticides, pest resurgence, secondary pest outbreak, build up of insecticide residues in oil and cake beyond the permissible limit and the degradation of the environment (Singh, 2001; Singh and Sharma, 2002). Therefore, it is imperative that available pest management tactics should be such that the situation is not aggravated to a point of no return. Keeping this in view, an attempt is made here to review the available information on the integrated management of *L. erysimi*, so that an economical and effective management strategy may be framed (Dhaliwal and Arora, 1996).

Specificity of *L. erysimi* to oilseed *Brassica* crops

The myrosinase-glucosinolate system has long been the defining phytochemical character of the order Capparales. The enzyme myrosinase exists in the form of a group of isozymes in family Brassicaceae. These hydrolyse glucosinolates, a diverse group of sulphur containing glucosides, present in all cruciferous plants to yield D-glucose, hydrogen sulfate, hydrogen and nitriles, thiocyanates, amines, isothiocyanates and epithionitriles depending upon such factors as substrate, pH or the availability of ferrous ions. Evidences suggest that, *in vivo*, glucosinolates and their volatile degradation products be involved in the interactions between cruciferous hosts and their potential pathogens, herbivores and symbionts (Bones and Rossiter, 1996). The volatile degradation products in intact or wounded plants have been implicated as attractant or repellent for mustard aphid depending on concentration (Dilawari and Atwal, 1989). The selectivity of mustard aphid, *L. erysimi*, a specialist pest, with respect to probing pattern and diet uptake was observed when the diet was supplemented with such extracts from host plants of varying susceptibility to the aphid (Dilawari and Atwal, 1987). Moreover, under field conditions, the aphid was found to colonise the cultivars having low amount of glucosinolates (Dilawari and Dhaliwal, 1996). Mac Gibbon and Benzenberg (1978) have shown that *L. erysimi* is also known to possess myrosinase enzyme. These

myrosinases exhibit electrophoretic mobilities distinct from those of isozymes of their host plants (Anita Kumari *et al.*, 2001).

Myrosinase, the glucosinolate degrading enzyme, is known to exist in several different forms which may have different levels of activities (Mithen, 1992). The studies on myrosinase isozyme from various cruciferous cultivars, *viz.*, *Brasica napus, B. carinata, B. campestris, B. juncea* and *Eruca sativa* varying in susceptibility to mustard aphid attack, demonstrated polymorphism ranging from one to three isozymes. Altogether, there are four isozymes. First isozyme (Rf = 0.07) is present in *B. napus*, *B. carinata* and *B. juncea* while another one (Rf =0.23) is present in *B. carinata, B. juncea* and *E. sativa*. The isozymes of *B. campestris* (Rf= 0.14) and *B. carnata* (Rf = 0.44) are distinctly different from all others (Fig. 1a). The volatile aglucone profiles of these cultivars shows qualitative and quantitative variations with respect to isothiocyanates of Ho-butenyl-,allyl-, butenyl- and Ho-indolyl-glucosinolates. Allylisothiocyanate is present in all the species while Ho-indolyl-glucosinolate is present in *B. juncea* and *B. carinata*. Isothiocyanate of Ho-butenyl glucosinolate is absent from *B. juncea* and *B. napus* while present in *B. carinata, B. campestris* and *E. sativa,* though amount is maximum in *E. sativa* (Table 1). The distribution pattern of myrosinase isozyme has been reported to be organ, species and age specific (Bones and Rossiter, 1996). It has been postulated that the particular isozyme corresponds to endogenous conditions found in that plant or to conditions found in target organism or to a particular glucosinolate that dominate the profile of that tissue . Different aglucone profiles are known to be the result of different isozyme patterns (James and Rossiter, 1991).

The glucosinolates have their impact on insect-plant interactions in *Brassica*, individually. The comparison of major volatiles from host plants *viz.*, *B. carinata* and *B. napus* and mustard aphid feeding on these hosts (Table 2) reveals the presence of four common isothiocyanates (Ho-butenyl-gln, allyl-gln, butenyl-gln and Ho-indolyl-gln) in host as well as in the aphid although in different amounts. Blum (1992) also reported the presence of identical isothiocyanates from *B. campestris* and *L. erysimi*. These observations indicate that these aglucones are sequestered in the aphid which are either metabolized and incorporated in the body for other adaptive functions (Picket and Griffiths, 1980) or may act as sink of nutrients like nitrogen and sulfur (Bones and Rossiter, 1996).

The isozyme pattern of the enzyme collected from the aphid feeding an rapeseed-mustard cultivars are quite distinct in the aphid from those of the cultivars (Fig.1b). The isozyme with Rf = 0.39 is universally present in the aphid while the other one with Rf = 0.05 is induced in response to specific type of glucosinolates. The presence of myrosinase in the body of the aphid indicates that the aphid metabolizes sequestered glucosinolates for some specific purpose. The aglucones, being insoluble in water cannot be eliminated as such and are probably incorporated into the species specific alarm pheromones of mustard aphid (Picket and Griffiths, 1980). In this way, glucosinolate-myrosinase system of crucifers and its herbivorous mustard aphid has an evolutionary significance of utilization of glucosinolates by the aphid which are otherwise toxic to non-crucifer feeding insects (Anita Kumari *et al.*, 2001).

Table 1 Volatile isothiocyanate composition (µg/g) of cruciferous species

Relative retention time (R_{rt})	Glucosinolates	Cultivar				
		Brasica carinata (Hc-9001)	*Brasica juncea* (RC-199)	*Brassica napus* (Midas)	*Brassica campestris* (BSH-1)	*Eruca sativa* (TMH-52)
0.88	Ho-butenyl	11.91	-	-	21.50	26.70
1.00	Allyl	8.82	33.88	20.00	27.20	18.80
1.14	Butenyl	2.38	5.64	-	15.00	-
1.24	Unidentified	4.59	10.16	87.00	5.16	6.77
1.31	Ho-indolyl	3.18	10.84	-	-	-

Source: Anita Kumari *et al.*, 2001.

Table 2 Volatile isothiocyanate content (µg/g) of *Brassica* host plants and mustard aphid

Relative retention time (R_{rt})	Glucosinolates	Host plant		Mustard aphid feeding on	
		B. carinata (PC-5)	*B. napus* (GSH-1)	*B. carinata* (PC-5)	*B. napus* (GSH-1)
0.88	Ho-butenyl	109.00	112.00	25.00	122.00
1.00	Allyl	33.00	4.29	13.00	3.50
1.14	Butenyl	6.93	7.30	12.42	7.60
1.31	Ho-indolyl	4.25	3.13	2.35	4.03

Source: Anita Kumari *et al.*, 2001.

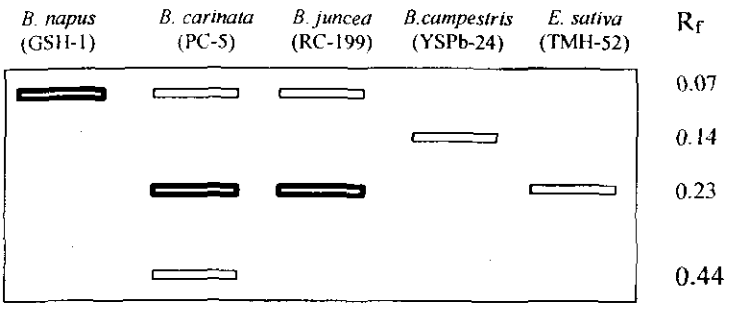

Fig. 1a. Zymogram showing the patternn of myrosinase isozymes from different cruciferous cultivars

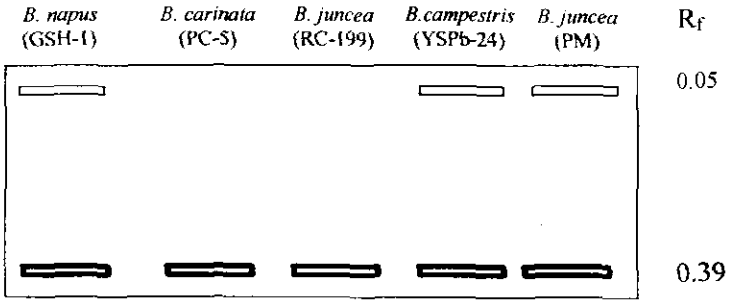

Fig. 1b. Zymogram showing the patternn of myrosinase isozymes from mustard aphid feeding on different cruciferous cultivars
Source: Anita Kumari *et al.*, 2001

Life History

The apterae *L. erysimi* are small to medium sized aphids, yellowish green, grey green or olive green covered with a white wax bloom. No marginal tubercles on abdominal segments I and VII. The aphid shows a longitudinal row of impressed areas on each side of the mid-abdominal dorsum. Antennae with weakly developed tubercles and no secondary sensoria, processus terminalis 2.0-2.25 times the base of the segment VI . Siphunculi pale to dark brown, rather shorter but longer than the cauda, tapering or nearly clavate. Cauda elontate with 4-6 hairs. Two hairs are present on the first segment of the hind tarsus. Alatae have a dusky green abdomen with conspicuous dark lateral sclerites and dusky wing veins (Basu and Banerjee, 1958; Blackman and Eastop, 1985; Bhattacharya, 1990).

In India, *L. erysimi* appears on the mustard crop in November and continues up to March, having highest populations during mid-February to mid-March (Singh and Verma, 1990; Rana *et al.*, 2001; Rai and Singh, 2001; Sekhon, 2001). The temperature between 20-25°C, average weekly rain fall 39 mm and RH 72% are favourable for the population build up of mustard aphid. However, lower atmospheric temperature (3.0-14.5°C; mean 7.8°C), heavy weekly rain fall of (73 mm), hail storm and high humidity (> 92 %) adversely affect the population of *L. erysimi* (Singh and Rawat, 1979; Rana and Bisht, 1988; Singh and Verma, 1990; Rana *et al.*, 2001)

At the advent of spring during March/April when the average temperature rises above 28°C and the mustard crop matures, the alatoid viviparous forms appear in huge numbers and migrate towards hills from where they return to the plains during late autumn when the cruciferous crops are abundantly available. At first, the immigrant alate forms appear and they multiply very slowly (38-40 aphids/10 cm central twig) parthenogenetically up to the last week of January and the apterae contribute largest population (148-163 aphids/10 cm central twig) in the third week of February. In March, again the alatae become abundant (4-23 aphids/10cm twig), followed by a decline in the aphid population (Kurl and Mishra, 1979; Singh and Rawat, 1979; Mishra and Kurl, 1983; Singh *et al.*, 1983; Rana and Bisht, 1988; Singh and Verma, 1990; Rana *et al.*, 2001).

The different parts of mustard plant exert influence on the growth and development of aphid. The nymphs develop at very fast rate and require short nymphal period (6.6 days) on leaves, while they took longest period (9.0 days) when feed on pods. The aphids complete their total life cycle (nymphal period+ adult longevity) in 12.2 days on flowering

shoots and require 22.4 days on stems. The fecundity was less i.e., 8.4 nymphs on inflorescence and highest (61 nymphs) on stems. The adult longevity has also been found to be shortest (5 days) on inflorescence and longest (14.4 days) on stems. All nymphs reared on pods develop into alatae, whereas, the nymphs reared on inflorescence and leaves remained in apterous form (Singh *et al.*, 1983).

Population count and economic threshold

For crop protection point of view, a quick estimation of aphid population density is required. Very often, the crop inspectors aim only at determining whether an economic threshold has been reached or not. The population count methods and economic threshold levels commonly followed in India are described below.

Population count

1. Select 10 plants at random and observe the whole plant for recording the aphid number/plant. Count the aphids (nymphs, apteraus and alatae) from different parts of the whole plant (twigs, leaves, main stem, branches, flowers and pods) at weekly interval starting from the first appearance of the aphid and continue till harvesting (Rana *et al.*, 2001). This method is followed in case of low population density.
2. Select 100 plants from the mustard field and tag them. Take the total population count from the top 10 cm central shoot of the tagged plants at weekly interval from the first appearance of *L. erysimi* in the field until harvest (Rai and Singh, 2001). This method is used to determine the seasonal and spatial distribution of aphids in the field.
3. Grow mustard crop in a plot size of 2.7 x 5m. Select 30 plants at random from this plot and record aphid population from 15 cm long central twig of each plant at an interval of one month, three times in the season (Singh *et al.*, 1990a).
4. Select 10 plants at random and tag them. Count the aphids from 15 cm long central twig of the selected plants per replication (60 plants per treatment). Take observations at regular weekly intervals (Singh *et al., 1990b).*
5. The following method is adopted to find out the number of aphids present on a plant when visual/absolute counting of aphids in difficult (Singh and Singh, 1994).

Length of the twig infested with mustard aphid	Number of aphids present
1 mm	10±1
2 mm	20±1
3 mm	30±1
4 mm	40±1
10 mm	100±1

6. Select three plants at random from the standard plot. Record aphid count from upper, middle and lower portion from each selected plant at each observational period. Note aphid population in the above manner at weekly intervals starting with the incidence of aphid population till harvest of the crop (Singh *et al.*, 1989).
7. Take the plot size of 5m x 2.5 m, select 5 plants at random for population count per plot and note aphids/10 cm terminal shoot/plant. Select 20 plants/plot at random and calculate per cent plant infestation. Take these observations at weekly intervals throughout the period of aphid incidence (Bakhetia and Ghorbandi, 1989; Bakhetia *et al.*, 1989). For determining the degree of association between the aphid population and percent plant-infestation, work out the correlation coefficient ® and the regression equation (Y = a + bx).

   Where , Y = yield (kg/ha)

   a = constant representing the average yield of uninfested plot

   b = regression coefficient (damage inflicte by each unit of aphid population per cent plants infested by the aphid)

   x = The aphid population or per cent plant infestation.
8. In order to evaluate the insecticidal dusts, grow the mustard crop in plot size 3 x 3m^2 or 2 x 2 m^2. Phadke and Prasad (1989) evaluated five insecticidal dusts, such as quinalphos 1.5 %, malathin 5%, phenthoate 2%, BHC 10% and chlorpyriphos 1.5% and compared it with untreated control. All the insecticidal dusts were applied @ 25 kg/ha in two split doses. The first application of 15 kg/ha was done after the first appearance of aphids on inflorescence shoots and the second application of 10 kg/ha was done after an interval of 20 days. Five numbers of inflorescence shoots were selected at random from each plot and observations on aphid incidence before and after 1, 3, 7, 14 and 20 days of the chemical treatment were taken on 10 cm length of selected inflorescence shoots.
9. Misra and Singh (1990) evaluated the efficacy of soil application of systemic granular insecticides, *viz.*, aldicarb 10 G, carbofuran 3 G, mephospholan 5 G, phorate 10G, disulfotan 5 G and disulfoton 5 G against *L. erysimi* during the rabi seasons of 1979-80 and 1980-81. The granules were applied @ 1.0 and 2.0 kg a.i./ha in 6 cm deep furrows opened by hand hoe on one side of the plant row 35 days after sowing in the first year and 77 days after sowing in the second year. Immediately after application, the granules were covered with soil and a light irrigation was given. Aphid counts were made from the 15 cm central top shoot of the randomly selected five plants per plot on 7th, 14th, 21st, 28th, 35th, 42nd, 49th and 56th day after application.

10. Rana et al. (1995) noted the absolute population of mustard aphid on 10 randomly selected plants per treatment on first day of every standard week starting from its appearance until harvest of the crop.

11. Kotwal and Singh (1994) had grown Indian mustard variety 'RLM 198' during rabi 1990-91 in 4 x 2.5 m plot size at a spacing of (30 x 10) cm. Foliar application of insecticides (phosphamidon 0.03%, oxydemeton methyl 0.03%, dimethoate 0.03%, endosulphan 0.034% and 0.07%, monocrotophos 0.035%, malathion 0.05%, chlorpyriphos, 0.025% and 0.05%) were evaluated by spraying with a foot sprayer at the rate of 750 litres of spray fluid/ha. Observations on aphid incidence before and 3, 5, 7, 10, 15 and 20 days after insecticidal treatment were taken on 10 cm length central shoots of five plants selected at random from each plot. The experiment was conducted in a Randomized Block Design with three replications.

12. Singh et al. (2001) conducted a field experiment in a Randomized Block Design with four replications to study the bioefficacy of plant based synthetic compounds (Benzaldehyde, Benzyl benzoate, Methyl benzoate and Methyl salicylate) with neem soap against L. erysimi in yellow sarson by taking plot size of 2 x 3.6m and plant spacing of 45 x 15 cm. Different concentrations (0.025, 0.05 and 0.1%) of synthetic compounds with two controls one with neem soap (0.025, 0.05 and 0.1%) and the other simply water were sprayed with the help of hand operated sprayer. The aphid populations before spray and 24, 48, 72 and 96 h after treatment were recorded on 10 randomly selected plants on 10 cm central shoot per plot.

13. The alate population of aphids infesting the mustard crop can be monitored by using yellow coloured iron tray filled with water of 43 cm x 30 cm x 10 cm in size and placing at a height of 152 cm in the four corners of the experimental plot throughout the crop season. Count the alate aphid population falling in the yellow water trap and refill the tray with fresh water everyday for new catches (Roy and Boral, 2002a).

14. Count the mustard aphid population from 10 cm centract twig of ten randomly plants in each replication (Roy and Baral, 2002a and 2002b).

Economic threshold (ETH)

Economic threshold is the pest population density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level (EIL) (Atwal, 1986). The economic threshold of a particular pest is governed by a number of factors such as the crop variety and its growth stage, season and the changes in the price of produce, insecticide and labour (Headley, 1972; Farrington, 1977; Bakhetia et al., 1988). The ETH values are also of great significance under variable agro-ecological situations prevailing in different states of India (Table 1).

Table 3 Economic threshold levels (ETL) of mustard aphid in different states

State	Number of aphids per 10 cm main shoot
Assam	28-29 aphids and 30% plant infestation in toria
Haryana	9-19 aphids and 30% plant infestation in mustard
Orissa	44 aphids in toria
Punjab	50-60 aphids and 40-50% plant infestation in mustard
Rajasthan	26-28 aphids
Uttar Pradesh	13-15 aphids

Integrated management of mustard aphid

Based upon review of literature, it is revealed that the following IPM strategy is recommended to control aphid population in rapeseed-mustard crops.

Cultural control : It comprises regular farm operations, which is so performed as to destroy the aphid pests or to prevent them from causing injury (Atwal, 1986).

a) Date of sowing: The early sown crop (up to 20th October) escapes aphid infestation because flowering is over and plant becomes hardy before the peak period of infestation (Singh et al., 1984; Srivastava and Singh, 2003).

b) Empirical methods: Initially the mustard aphid appears in the last week of December or first week of January on northeast border plants or on few plants on border of the fields or in some pockets of the crop. Therefore, removal and destruction of the infested twigs will help in checking to further development and spread of the aphid pest (Singh et al., 1995).

c) Fertilizer application: In general heavily fertilized Brassica crops are more prone to the incidence of mustard aphid (Singh and Sharma, 2002). According to Singh et al. (1995), increase in level of nitrogen application results in an increase of mustard aphid infestation while significant reduction in infestation occurs on account of addition of phosphate and potash. It was observed that application of 40 kg N (20 kg less than the recommended dose), 80 kg P_2O_5 and 40 kg K_2O/ha responded appreciably in reducing the aphid infestation with resultant increase in yield of the mustard crop (cv.Varuna). Potassium applied @ 80 kg/ha reduced the infestation of aphids without use of insecticides (Singh et al., 1997).

d) Water management: Water stress reduces amino acid concentration in mustard plants, which consequently reduces fecundity of the L. erysimi feeding on mustard crop grown under water stressed conditions (Sidhu and Kaur, 1977; Chada and Arora, 1982). Water stress also

encourages wing formation and migration of mustard aphids (Harrewijn, 1989).

e) Intercropping: Goel and Tiwari (2004) intercropped mustard with potato, wheat, gram (*Cicer arietinum*), linseed, fenugreek and coriander and also as a sole crop at Pantnagar in order to study the effect of intercropping on the incidence of *L. erysimi* on mustard. *L. erysimi* nymphs and adults were counted from 10 randomly selected plants in each plot at weekly interval from 89 to 117 days after sowing. Aphid population (per 10 plants) was lowest when mustard was intercropped with coriander, followed by linseed, fenugreek, gram, wheat and potato. The maximum aphid population was recorded when mustard was grown as a sole crop.

Use of resistant varieties : Among the rapeseed mustard crops, *Brassica juncea* and *B. carinata* genotypes are found tolerant to aphid attack as compared to the B. campestris genotypes (Kalra *et al.*, 1987). *B. juncea* strains, i.e., Laha 101, T 6342, Rai 236, Rai 237, RLM 198, RLM 202, B 85, RW 2-2, RH 7846, RH 7847, Purple Mutant and RC 199 (apetalous) and *B. carinata* strains *DLSC 1 and DLSC 2 are fairly resistant to mustard aphid* (Rohilla *et al.*, 1999). *B. tournefortii* also harbours relatively low aphid population indicating tolerance (Singh and Sharma, 2002).

Bakhetia *et al.* (2002) screened 2270 lines of *Brassica juncea* L. for their resistance to *L. erysimi* at two locations (Ludhiana and Bathinda) in Punjab on the basis of aphid infestation index (A.I.I.), aphid population per plant and percentage of plants harbouring aphid colonies for two years (1991-93). None of the entries registered the lest susceptible group on the basis of all the three parameters at either location. However several genotypes were graded in the resistant group on the basis of two parameters in either year or one parameter in both the years. The entries showing low to moderate level of resistance to the mustard aphid included, JMG 134, JMG 293, JMG 386, CSR 61, CSR 128, CSR 136, CSR 147, CSR 148, CSR 1055, CSR 1244, B 89, DN 379, CS 4024 at Ludhiana and CSR 1086 and R 7006 at Bathinda. It was opined that, these lines can be used in the breeding programmes aimed at developing resistant varieties through the conventional and/or novel approaches of breeding for pest and disease resistance.

Use of botanicals : Spraying of plant based synthetic compounds (benzyl benzoate, methyl benzoate, benzal dehyde and methyl salicylate) at 0.1 % concentration with neem soap (0.025 %) causes 75-85 % mortality of *L. erysimi* after 96 hours of application. Ethanolic extracts of rhizome of Curcuma longa (turmeric (6%), petals of *Tagetes patula* (marigold) (6 %) and roots of *T. patula* (4 %) causes 100 % mortality of the mustard aphids after 96 hours of application (Arya and Singh, 2001). Similarly, petroleum ether extracts of seeds of *Anona squamosa* (custard apple) leaves of *Ocimum sanctum* (basil) and *rhizomes of Zingiber officinale* (zinger) causes complete mortality of nymphs and adults of *L. erysimi* after 72 hours of application at 4 % concentration in distilled water using Triton X-100 as an emulsifier (Singh and Arya, 2001). The petroleum ether extract of leaves of congress grass, *Parthenium hysterophorus* Linn. at 1000 ppm showed severest detrimental influence on nymphal developmental period and adult emergence. The IC50 values calculated by applying the probit analysis are 100 ppm, 140 ppm and 800 ppm for 96-100 h, 48-52 h and 6-8 h old nymphs, respectively (Sohal *et al.*, 2000). Soil application of neem leaf powder @ 75 kg/ha at the time of sowing in furrows reduced the population of mustard saw fly, mustard aphid, *alternaria* blight and white rust diseases over control and increased the grain yield to the extent of 5.20 % over control (Srivastava and Singh, 2003).

Biotechnological approaches: *The amphiploid (Eruca sativa* x *Brassica campestris*) developed through protoplast fusion has proved promising for aphid resistance (Singh and Sharma, 2002).

Use of natural enemies : The natural enemies enlisted below (Agarwala and Bhattacharya, 1999; Chitra Devi *et al.*, 2002; Ahmad *et al.*, 2003; Devi *et al.*, 2003 , Singh *et al.*, 2003; Blande *et al.*, 2004; Purwar and Sachan, 2004; Soni *et al.*, 2004; Shenhmar and Brar, 1995; Awchar *et al.*, 1995) play an important role in the reduction of mustard aphid population in the field.

Hymenopterous parasites

Ichneumonoidea : Bracomidae : Aphidiinae	Chalcidoidea : Aphilinidae
Aphidius gifuensis Ashmead, *A. Matricariae* Haliday, *Diaretiella rapae* (Mc Intosh), *Ephedrus persicae* Froggat, *E. Plagiator* (Nees), *Lipolexis gracilis* Forster, *Lysiphlebus erysimi* Stary, *Proan volucre* (Holiday), *Trioxys brevicornis* (Haliday) and *T. indicum* Subba Rao and Sharma	*Aphelinus* sp nr. *flavipes* Kurdy

b) Predators

Coccinellidae : Coleoptera: *Brumoides suturalis* (Fab.), *Cheilomenes sexmaculatus* (Fab.), *Coccinella actopunctata* Fab, *C. septempunctata* L., *C. transversalis* Fab (=*C. repanda* Thunbarg), *C. transversguttata* L., *C. undecimpunctata* L., *Harmonia octomaculata* Fab. *Hippodamia* (Adonia) *variegata* (Goeze), *Micraspis discolor* (Fab.), *Monolepta signata* (Oliver), *Pania luteopustulata* (Milsant) (= *Oenopia luteopustulata* Mulsant), *Pseudaspidimerus circumflexus* (Motscchulsky), *Scymnus pyrocheilus* Mulsant and *S. xerampelinus* Mulsant;

Syrphidae : Diptera: *Allograpta javana* (Wiedmann), *Betasyrphus aeneiformis* Brunetti, *B. isaacci* (Bhatia), *B. serarius* (Wied.), *Dideopsis aegrota* (Fab.), *Episyrphus analterns* (Macquart), *E. balteatus* (de Geer), *E. viridaureus* (Wiedmann), *Eupeodes* (Macrosyrphus) *Confrator* (Wiedmann), *Ischiodon scutellaris* (Fab.), *Melanostoma orientale* Wied., *Metasyrphus confrator* Wied., *Paragus crenatus* Thomson, *P. Serratus* Fab., *P. tibialis* Fallen, *Scaeva albomaculata* (Macquart), *S. pyrestri* (L.), *Sphaerophoria indiana* Bigot, *S.scripta* (L.), *S. voekerothi* Joseph and *Sphaerophoria* sp.;

Chrysopidae : Neuroptera: *Chrysoperla scalastes, C. Carnea;*

Hemerobiidae : Neuroptera: *Micromus timidus* Hagen

Birds :Gray Wag Tail bird.

Fungal pathogens

Beauveria bassiana, Cephalosporium aphidicola, Entomophthora sp., *Metarhizium anisopliae* and *Verticillium lecanii* were tried against aphids on rapeseed-mustard crops.

Studies on the relative abundance of the effective natural enemies of mustard aphid, *L. erysimi* during 2000-01, 2001-02 and 2002-03 in the farmers fields of eastern Uttar Pradesh, India revealed that population of the *C. septempunctata* was highest (41.97 %) followed by *C. transversalis, D. rapae, C. carnea, C. sexmaculatus. I. scutellaris* and *B. suturalis* with 25.03, 11.78, 7.64, 6.00, 3.93 and 3.65 % relative abundance, respectively. The occurrence of selected natural enemies was observed on 20th December during all the years of experimentation. All the natural enemies showed increasing trend till harvest of the crop except C. *carnea* and *I. scutellaris*. The population of these two natural enemies started decreasing after January onwards. During the month of January the relative abundance of *C. carnea* was highest followed by *I. scutellaris*. Whereas during the month of February onwards coccinallids occupied major share with maximum relative abundance of *C. septempunctata* followed by *C. transversalis* (Singh *et al.*, 2003).

Studies on the influence of temperature (20, 25, 27, 30 and 35°C) on certain biological attributes of C. septempunctata feeding on *L. erysimi* revealed that, its developmental period was shortest (11.7±0.09 days) at 35°C and longest (20.6±0.35 days) at 20°C. However, 30°C was found as the most suitable temperature for *C. septempunctata* where hatching percentage, larval survival, adult emergence, growth index, oviposition period and fecundity were maximum (Srivastava and Omkar, 2003).

According to Omkar and Srivastava (2003), the order of suitability of aphid species for *C. septempunctata* is *L. erysimi* > *Myzus persicae* > *Aphis craccivora* > *A. gossypii* > *Uroleucon compositae* > *A. nerii*. The pre-adult development was shortest (14± 0.12 days) when fed on *L. erysimi* and longest (23±0.10 days) on *A. nerii*. Immature survival, adult emergence, growth index, relative growth rate, development rate, male and female longevity, oviposition period, fecundity and hatching per cent were maximal, i.e., 73±0.9%, 90±1%, 9±0.2, 2±0.02, 0.07, 81±2 days, 86±1.45 days, 70±1.3 days, 1764± 8.4 and 88±1.05, respectively when *C. septempunctata* were fed on *L. erysimi*. The same parameters were minimal, i.e., 44±1.33%, 72±2%, 2±0.08, 0.5±0.02, 0.04, 44±1.39 days, 54±1.00 days, 16±0.60 days, 203.20±11.83 and 48.68±2.06, respectively on *A. nerii*. The weight of different ladybird life stages were maximal after feeding on *L. erysimi* and minimal on *A. nerri*.

Singh *et al.* (2003) studied the preying capacity of *C. carnea* against *L. erysimi* under controlled conditions. On average, 22, 77 and 161 aphids were consumed by 1st 2nd and 3rd instar larvae of *C. carnea*, respectively, with an average of 260 aphids by single larva during its development. The average per day consumption by 1st, 2nd and 3rd instar larvae of *C. carnea* was 4, 19 and 28 aphids, respectively.

The parasitization of *L. erysimi* by *D. rapae* was investigated at Palampur, Himachal Pradesh, India on *B. campestris* var. sarson (BSH-1) sown in October 1998. *D. rapae* appeared in the second week of January and maximum parasitization (51.0%) was recorded in the second week of March when mean maximum temperature, mean minimum temperature and relative humidity was 22.5°C, 10.3°C and 36%, respectively (Dogra *et al.*, 2003).

Singh *et al.* (2004) estimated different life-table statistics of *D. rapae*, such as age-specific survivorship, reproductive and net fecundity rates, intrinsic rate of natural increase, doubling time of the population and generation time under constant laboratory condition. The female parasitoid survived 11±2.8 days . The length of period of intensive oviposition was 5±0.3 days. Total fecundity rate (Rt) and net reproductive rate (Ro) were 230±24.9 SD progeny/female and 142±14.7 SD daughters/female, respectively. The intrinsic rate of natural increase was estimated 0.27. The generation time (GT) was observed to be 19 days. The doubling time of the population was estimated 2.6 days. Progeny sex ratio was female biased (P= 0.383). These informations will be helpful while utilizing *D. rapae* as a bioagent of *L. erysimi*.

Ahmad *et al.* (2003) conducted experiments in the laboratory and in greenhouses to study the effect of neem treated aphids as food/hosts of their predators and parasitoids. Of three neem preparations (neem oil, neem kernel water extract and NeemAzal-T/S®) sprayed upon eggs, only neem oil (NO) exerted a negative impact on the hatching rate of *C. septempunctata* and *C. carnea*. First instar larvae of *E. balteatus* proved to be highly

susceptible, when feeding 24h on aphids sprayed with neem kernel water extract (NKWE). First instar larvae of *C. septempunctata* showed a very high mortality when feeding on aphids sprayed with different neem preparations. Aphid feeding and life span was reduced. Second instar larvae of *C. septempunctata* were far less susceptible when feeding 48 h on neem sprayed aphids than first instar, the time of their development prolonged and aphid consumption reduced. Larvae of *C. carnea* proved to be less susceptible, when feeding on neem sprayed aphids than *E. balteatus* and *C. septempunctata*. In *C. carnea*, however, significant influences were also observed in aphid consumption, time of development, mortality, longevity and rate of deformity. Neem oil containing a very low concentration of azadirachtin A, had stronger negative effects than NeemAzal-T/S®, in all observations. In the parasitoid, *D. rapae*, NKWE application to the soil induced negative reactions, when aphids on these plants were parasitised; low per cent parasitization, lowered mummy weight, low emergence rate of adults of F_1 and even of F_2. Foliar sprays of NKWE had less severe effects on this parasitoid species.

Men *et al.* (2002a and b) evaluated some biopesticides and insecticides for their safety to *D. rapae*, a potential parasitoid of the mustard aphid (*L. erysimi*) on Indian mustard cv. Pusa Bold at Akola, Maharashtra, India. It was found that *B. thuringiensis* (1 kg/ha) and Neemark (1 %) were the safer treatments followed by neem leaf extract (5%), *B. thuringiensis* at 0.5 kg/ha + endosulfan (0.03 %), endosulfan (0.05 %), Achook (0.15 %) and neem seed extract (5 %). Dimethoate (0.03 %) proved toxic to the hyperparasitoid.

The resistance to methamidosphos (methamedophos) and methomyl and the effect of synergists on the insecticides in susceptible - (S) and resistant -(R) strains of D. rapae collected from Fujian, China were detected using the residual film method. The kinetic parameters of acetylcholinesterases (AchE), the activity of detoxification enzymes in *D. rapae* and its host *L. erysimi* and the inhibition of synergists on enzyme activities in *D. rapae in vivo* were also investigated. Compared to the susceptible strain, the resistance to methamedosphos and methomyl was 5.6 fold and 9.1 fold, respectively in the field collected *D. rapae*. Obvious synergisms of piperonyl butoxide (PB), triphenylphosphate (TPP) and diethyl maleate (DEM) to these insecticides were found in *D. rapae*, the synergism of PB being the highest. The synergisms of PB to the two insecticides in the R strain of *D. rapae* were significantly higher than those in the S strain. PB, TPP and DEM did not inhibit AChE activity, but strong inhibition of carboxylesterase (CarE) activity was caused by PB and TPP, and glutathione S - transferase (GST) activity by DEM. The apparent Michaelis-Menten constant and maximal velocity of AChE and the activities of CarE and GSTs in the S strain were similar to those in the R strain of *D. rapae*. In addition, a comparison of kinetic parameters of AChE and the activities of CarE and GSTs between *D. rapae* and *L. erysimi* were conducted. The results indicated that the resistance mechanism to methamidophos and methomyl in *D. rapae* is related to AChE insensitivity and detoxication enzymes (Gang and ShuRen, 2003).

Judicious use of insecticides

Chemical control would continue to be the first line of defense against mustard aphid particularly under outbreak situation. Various insecticides *viz.*, oxydemeton methyl 0.025%, phosphamidon 0.025%, dimethoate 0.03%, quinalphos 0.025%, endosulfan 0.05%, Chlorpyriphos 0.03% and monocrotophos 0.05% have been advocated on all India basis. Under dry land conditions the use of insecticidal dusts, *viz.*, methyl parathion 2% and endosulfan 4% @ 25 kg/ha are found very effective (Singh *et al.*, 1984; Singh and Sharma, 2002; Srivastava and Singh, 2003). It has been observed that oxydemeton methyl 0.025% and endosulfan 0.035% are very safe to the pollinators and at the same time are very effective against aphids (Singh *et al.*, 1987). According to Men *et al.* (2002b), endosulfan 0.03%+0.5 kg/ha *Bacillus thuringiensis* could effectively control *L. erysimi* in mustard.

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Combining ability for yield and its components in groundnut, *Arachis hypogaea* L.

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Abstract

Nine lines were crossed with four testers in a L x T mating design to estimate the combining ability for yield and its component traits in groundnut, *Arachis hypogaea* L. The variance due to *sca* was greater than *gca*, which indicated the preponderance of non-additive gene action for plant height, number of primaries, secondaries, mature pods, immature pods and pod yield/plant. The parents *viz.*, CO 3, TNAU 325, TNAU 387 and M 13 can be considered as superior parents in the present study as they recorded high *per se* with positively significant *gca* effect for pod yield/plant. Among the 36 hybrids evaluated, crosses *viz.*, CO 3 x M 13, TNAU 387 x M 13, CO 3 x ICGV 93260, TNAU 325 x M 13 and CO 2 x GG 2 were considered as superior hybrids as they observed high *per se* and non-significant sca effect for pod yield/plant. These superior crosses involved parents with significant positive *gca* effects which in turn suggested the possible role of additive gene action in these crosses.

Key words: Groundnut, combining ability, gene action, yield, yield components

Introduction

Many traits of economic importance in groundnut are quantitatively inherited. The exploitation of genetic variability (additive gene effect) of these traits through hybridization and selection is the primary focus of most groundnut improvement programmes. Plant height, number of primaries, secondaries and mature pods are important yield components, in view of their positive correlation with pod yield. Hence, there is an urgent need to collect basic information about these traits in order to conceptualize breeding strategies suited to specific conditions. The objective of this study is to determine the combing ability of 13 parents for yield and yield components. The studies envisages to assess general combing ability of parents and specific combining ability of crosses through appropriate biometrical methods.

Material and methods

Parents were selected to include varieties and cultures that represent different botanical forms originated from diverse geographical locations (Table 1). Nine lines (CO 3, VRI 3, ALR 3, TNAU 325, TNAU 387, TNAU 379, Rose 7, CO 2, and VRI Gn 5) were crossed with testers (GG 2, M 13, ICGV 93260 and ICGV 96108) in a Line x Tester model during *kharif* 2001. Thirty six F_1 hybrids along with their 13 parents were grown in a Randomized Block Design (RBD) with two replications during *rabi*/summer 2001-2002 in the Cotton Farm, Tamil Nadu Agricultural University, Coimbatore. Both parents and F_1s were raised in 5 rows of 3 m length. At maturity, observations were recorded on 10 randomly selected plants from each entry in both replications for six quantitative characters *viz.*, plant height (cm), number of primaries, secondaries, mature pods, immature pods and pod yield/plant (g). The mean values of 10 observations were subjected to Line x Tester analysis (Kempthorne, 1957) to estimate combining ability effects. Analysis of variance (ANOVA) is performed to test the significance of difference among the genotypes including crosses and parents. If the differences are found significant, Line x Tester analysis is done. To test the significance of genotypic differences, treatment mean squares and error mean squares was compared with table value of 'F' at the desired level of significance. In the case of Line x Tester analysis, mean square due to lines and testers are tested against mean square due to line x testers. The later is, in turn tested against mean square due to error. Considering the mean performance and *gca* effects, the parents were ranked as good or high/poor or low combiners.

Results and discussion

The analysis of variance showed significant differences among hybrids for all the characters, while parents exhibited significant mean squares for all the characters except for number of mature and immature pods. The interaction effect of hybrids vs parents showed significant difference only for plant height and pod yield/plant (Table 1).

Analysis of variance for combining ability revealed that variances due to lines was significant for all the traits except number of immature pods while, variance due to testers was significant for number of secondaries, mature and immature pods and pod yield/plant. The interaction effect (line x tester) was significant for all the traits except pod yield/plant (Table 2). The variance due to specific

combining ability was greater than the variance due to general combining ability, which indicated the predominant role of non-additive gene action in the expression of these traits. Non-additive gene action for these traits was earlier reported by Senthil and Vindhiya Varman (1998), Vindhiya Varman and Senthil (1998) and Mathur *et al.* (2003).

The *per se* performance of parents was considered as the first important criterion for selection. Perusal of the *per se* performance of parents indicated that the parents Rose 7, ALR 3, CO 2 and CO 3 were high yielders among all the parents. The parent Rose 7 also registered significantly superior *per se* performance for number of primaries and secondaries/plant. All the four parents recorded low mean values for number of immature pods. Based on *per se* performance for pod yield/plant these four parents were identified as desirable parents.

The second criterion of selection is the general combining ability (*gca*) effects of parents as the parents with high mean values may not necessarily be able to transmit their superior traits to their progenies.

The results indicated that three lines *viz.*, CO 3, TNAU 325, TNAU 387 and the one tester, M 13 recorded significantly positive gca effects for pod yield/plant (Table 3). The line TNAU 325 also recorded positive and significant *gca* effects for number of mature pods and plant height. However, the parent is a poor combiner for number of immature pods. The tester parent M 13 exhibited positive and significant *gca* effects for number of secondaries and mature pods along with pod yield/plant. Makne (1992) reported M 13 as a good combiner for number of secondaries. Similarly, Vindhiya Varman and Senthil (1998) have also ascertained M 13 as a good combiner for pod yield and number of branches. These findings showed the consistent nature of the parent M 13 in the inheritance of these traits. Though, VRI 3 was a poor combiner for pod yield, it exhibited significant *gca* effects for plant height and number of mature pods. Similarly, the tester parent GG 2 observed poor *gca* effects for pod yield/plant whereas, it registered significantly high *gca* effects for number of mature pods and number of primaries. Vindhiya Varaman (2000 and 2001) observed poor gca effects for number of primaries and mature pods in GG 2. Among the lines, CO 2 was a poor combiner for number of primaries. Such a poor combining ability of the parent CO 2 for number of primaries have already been reported by Vindhiya Varman (2000). The lines Rose 7 and VRI Gn 5 were identified as good general combiners for number of primaries and poor combiner for numbr of immature pods, while TNAU 379 was a good combiner for number of secondaries.

Association between *per se* performance and *gca* effects was not evident in the present study. In fact, in many cases, the lines and testers with high mean had low *gca* effects indicating the ineffectiveness of choice of parents based on *per se* performance for hybridization. Selection of parents based on *gca* is more important than *per se* performance. Hence, based on *gca* effects, the parents *viz.*, CO 3, TNAU 325, TNAU 387 and M 13 can be considered as superior parents for future use.

Among the 36 crosses evaluated none of them recorded significantly superior mean pod yield/plant. However, the crosses *viz.*, TNAU 325 x M 13, CO 3 x M 13, CO 3 x ICGV 93260, CO 2 x GG 2 and TNAU 387 x M 13 recorded high mean pod yield, which was on par with the general mean. The cross TNAU 325 x M 13 also registered high mean number of mature pods while, another cross CO 2 x GG 2 observed high mean for number of mature pods and number of secondaries. Hence, based on *per se* performance, the above five crosses can be considered as superior for pod yield.

In contrast to the *gca* effects being attributable to additive genetic effects, *sca* denotes dominance and epistatic gene effects that are non-fixable. Parents with good combining ability and the resultant cross with non-significant *sca* are considered desirable for varietal development programme due to the presence of additive gene action. Even in crosses with significantly high *sca* effects, if one of the parents involved are good combiner, then, these crosses can also be considered for varietal development due to the presence of additive type of epistasis. However, in case of later, selection should be postponed to later generations, provided all the selected crosses should have desirable level of *per se* performance. In case of the hybrids with high mean, high *sca* and parents involved are poor combiners, they may be useful for hybrid development. But, there is no practical means of utilizing heterosis at present in groundnut. Hence, these hybrids are not useful. Thirty out of 36 crosses occupied the first five ranks for six characters (Table 4). Of these 30, 12 crosses were between High x High, five between High x Low and 13 crosses involved Low x Low *gca* parents.

Considering the performance for pod yield/plant, the crosses, CO 3 x M 13, TNAU 325 x M 13 and TNAU 387 x M 13 recorded non-significant *sca* effects and both the parents involved are good combiners. The gene action involved in these crosses may be of additive type. In the case of CO 3 x ICGV 93260 non-significant *sca* effect was recorded. However, one of the parents CO 3 was a good combiner and another parent ICGV 93260 was a poor combiner. The parents of the cross CO 2 x GG 2 were poor combiners. However, the cross registered significant *sca* effects and the gene action involved may be of additive type of interaction. Performance of other yield attributing traits indicated that the cross TNAU 325 x M 13 recorded significantly high mean number of mature pods and the parents exhibited significant *gca* effect, while the *sca* effect was non-significant, which indicates the possibility of rapid improvement of this character as it may

be under the control of additive gene action. The cross CO 2 x GG 2 showed high *per se* for number of mature pods. The tester parent GG 2 noticed significant *gca* effect and the other parent observed low *gca* effect. Same cross showed high *per se* for number of secondaries and the parents are of poor combiners. The cross exhibited significant *sca* effect, thus may also be selected for further genetic improvement.

From the foregoing discussion, it may be concluded that the crosses *viz.*, CO 3 x M 13, TNAU 387 x M 13, CO 3 x ICGV 93260, TNAU 325 x M 13 and CO 2 x GG 2 were rated as best crosses for further improvement by adopting pedigree method of breeding.

Table 1 ANOVA table for parents and crosses

Source	df	Mean squares					
		Plant height (cm)	Number of primaries	Number of secondaries	Number of mature pods	Number of immature pods	Pod yield / plant (g)
Replications	1	5.789	2.659	3.443	273.746**	24.380	2.101
Hybrids	35	38.857**	2.9065**	16.731**	73.499**	35.560**	35.179**
Parents	12	52.726**	2.209**	29.638**	25.256	15.636	123.102**
Hybrids vs Parents	1	119.874**	1.486	0.5131	0.4944	0.075	515.119**
Error	48	10.073	0.7831	3.004	23.670	13.041	6.772

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

Table 2 ANOVA table for combining ability analysis

Source	df	Mean squares					
		Plant height (cm)	Number of primaries	Number of secondaries	Number of mature pods	Number of immature pods	Pod yield / plant (g)
Replications	1	9.901	0.008	0.051	11.988	0.001	2.816
Line (females)	8	123.768**	6.777**	44.234**	159.079**	22.168	87.633**
Tester (males)	3	1.552	2.86	25.238*	212.669**	223.032**	77.441**
Line X Tester	24	15.216**	1.643**	6.499**	27.576**	16.591**	12.412
Error	35	5.318	0.176	1.914	10.148	3.925	7.893
GCA		0.637	0.034	0.275	1.238	0.511	0.613
SCA		4.948	0.733	2.292	8.713	6.332	2.259
GCA/SCA		0.128	0.046	0.120	0.142	0.081	0.271

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

Table 3 Estimates of general combining ability (*gca*) effects for yield and yield components in groundnut

Parents	Plant height	Number of primaries	Number of secondaries	Number of mature pods	Number of immature pods	Pod yield/ plant
Lines						
CO 3	0.10	-0.65**	-1.26*	-0.71	0.88	4.71**
VRI 3	1.79*	-0.74**	0.05	5.14**	-0.31	0.76
ALR 3	-1.18	-0.61**	-3.82**	-0.09	-3.05**	0.00
TNAU 325	5.23**	-0.16	-0.10	7.82**	-0.65	3.09**
TNAU 387	0.73	-0.41**	-2.51**	-2.30*	1.90**	2.32*
TNAU 379	-4.54**	0.07	2.81**	-4.41**	1.88*	-4.81**
Rose 7	-0.31	1.99**	3.30**	-6.61**	0.89	-4.71**
CO 2	4.96**	-0.52**	-0.17	-0.41	-1.88**	0.67
VRI Gn5	-6.78**	1.01**	1.72**	1.57	0.34	-2.05*
S.E.(gi)	0.815	0.148	0.489	1.126	0.700	0.993
Testers						
GG 2	0.01	0.38**	0.18	2.20**	2.71**	0.79
M 13	-0.21	-0.05	1.57**	3.66**	2.28**	2.46**
ICGV 93260	-0.21	0.18	-1.16**	-2.76**	-0.02	-0.94
ICGV 96108	0.41	-0.52**	-0.59	-3.09**	-4.96**	-2.31**
S.E. (gi)	0.543	0.099	0.326	0.751	0.467	0.662

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

Table 4 Estimates of specific combining ability (*sca*) effects of best five crosses based on *per se* performance

Characters	Cross	Mean	*sca* effect	*gca* status of parent	
				P_1	P_2
Pod yield per plant (g)	CO 3 x M13	23.82	-0.09	High	High
	TNAU 387 x M 13	24.69	3.17	High	High
	CO 3 x ICGV 93260	24.43	3.93	High	Low
	TNAU 325 x M 13	25.06	2.77	High	High
	CO 2 x GG 2	23.11	4.93*	Low	Low
Number of immature pods	CO 2 x ICGV 93260	2.70	-5.00**	Low	Low
	VRI 3 x ICGV 96108	3.35	-0.99	Low	Low
	ALR 3 x ICGV 96108	3.66	2.07	Low	Low
	CO 2 x ICGV 96108	3.66	0.90	Low	Low
	CO 3 x ICGV 96108	3.72	-1.80	Low	Low
Number of mature pods	TNAU 325 x M 13	37.60	3.30	High	High
	CO 2 x GG 2	34.50	9.90**	Low	High
	VRI 3 x GG 2	33.40	3.24	High	High
	VRI 3 x M 13	32.60	0.98	High	High
	TNAU 325 x GG 2	32.45	-0.39	High	High
Number of secondaries	Rose 7 x M 13	11.34	1.14	High	High
	CO 2 x GG 2	10.30	4.96**	Low	Low
	Rose 7 x ICGV 96108	9.73	1.70	High	Low
	TNAU 379 x M 13	9.46	-0.25	High	High
	VRI Gn 5 x M 13	9.43	0.81	High	High
Number of primaries	VRI Gn 5 x GG 2	8.95	2.70**	High	High
	Rose 7 x ICG 93260	8.64	1.60**	High	Low
	Rose 7 x GG 2	7.64	0.41	High	High
	Rose 7 x M 13	6.00	-0.81**	High	Low
	TNAU 325 x ICGV 93260	5.65	0.77**	Low	Low
Plant height (cm)	VRI Gn 5 x M 13	18.25	-1.36	Low	Low
	VRI Gn 5 x ICGV 96108	18.31	-1.93	Low	Low
	VRI Gn 5 x GG 2	20.19	0.36	Low	Low
	TNAU 379 x ICGV 96108	20.65	-1.82	Low	Low
	TNAU 379 x ICGV 93260	20.82	-1.02	Low	Low

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Genotype x environment interaction in groundnut, *Arachis hypogaea* L. based on AMMI analysis

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Abstract

Genotypic adaptation in the different agro-ecologies is determined by studying genotype x environment (GE) interaction. Additive main effect and multiplicative interaction (AMMI) analysis was performed on seed yield of 12 groundnut (*Arachis hypogaea* L.) genotypes tested over 16 environments during rainy season 2000 and 2001 to ascertain GE interactions. Genotype effects, environment effects and interaction components were significant. Genotypes exhibited differential adaptation (narrow or broad) by scoring slight or sizable interactions. AMMI analysis identified TG 37A as highly productive and broadly adaptable genotype. It also grouped environments into productive or unproductive environments with or without interactions. Some specific adaptations like GPBD 4 to Aliyarnagar and Udaipur were identified.

Key words: *Arachis hypogaea*, GE interaction, AMMI analysis, adaptation

Introduction

The germplasm assessment is a crucial activity in plant breeding. Multi-environmental (location, season or year) evaluation of genotypes is effective in understanding genotype x environment (GE) interaction, which enables in identifying productive genotypes having location-specific, season-specific or wider adaptation. Genotypic performance in multi-environment trials based on genotypic means, usually obtained through analysis of variance (ANOVA), is less predictable and difficult to interpret because of large portion of GE interaction. ANOVA is inadequate in effectively treating complex yield data in such trials (Zobel *et al.*, 1988). In additive main effect and multiplicative interaction (AMMI) model, the main effects or additive part (genotypes or environments) of the model are analyzed by ANOVA and GE interaction or multiplicative part is analyzed by principal component analysis (Zobel *et al.*, 1988). AMMI analysis captures large portion of GE interaction; separates main and interaction effects clearly; partitions agro-climatic regions into sub-regions; identifies specific adaptations based on interaction patterns and genotypic rankings (Gauch, 1992; Gauch and Zobel, 1997; Kang, 2002; Casanoves *et al.*, 2005).

Bhabha Atomic Research Centre (BARC) has been involved in the genetic enhancement of groundnut (*Arachis hypogaea* L.) through a blend of mutation and recombination breeding since late fifties. As a result, diverse groundnut germplasm consisting of induced mutants, mutant derivatives, breeding lines etc., have been developed and maintained at Trombay (Badigannavar *et al.*, 2002). National groundnut evaluation trials in different environments (locations and years) are organized through All India Coordinated Research Project on Groundnut (AICRPG) (Anonymous, 2004). The Trombay groundnut (TG) germplasm lines on evaluation in AICRPG at state and/or national level qualify for commercial release to the farmers.

The objective of the present study was to determine the effect of GE interaction on the seed yields and to understand the specific or general adaptation of new TG genotypes evaluated through AICRPG for two years over 16 environments (locations) across the country using AMMI analysis.

Materials and methods

Under the AICRPG, the initial varietal trial (IVT) I and II for Spanish bunch group (ssp. *fastigiata* var. *vulgaris*) were conducted during rainy season (June-October), 2000 and 2001, respectively (Anonymous, 2002). Trial entries comprised of TG 36A, TG 37A, TG 38B and TG 38C from BARC, Mumbai; GPBD 4 and Dh 2000-1 from University of Agricultural Sciences, Dharwad; K 1268 and K 1271 from Agriculture Research Station, Kadiri; TNAU 262, TNAU 266, TNAU 325 from Tamil Nadu Agricultural University, Coimbatore and a national check variety, JL 24. All the 12 genotypes were evaluated in 16 locations, namely Durgapura, Hanumangarh and Mainpuri from Zone-I; Junagadh and Udaipur from Zone II; Akola, Khargone and Jalgaon from Zone III; Chiplima and Jhargram from Zone IV; Aliyarnagar, Chintamani, Dharwad, Digraj, Kadiri and Vriddhachalam from Zone V. All the 16 testing centers were treated as 16 environments.

For the AMMI analysis, seed yield (kg/ha) data was taken from the IVT I and II trials (Anonymous, 2002). In these trials, the zonal and local check varieties used, differed over locations/zones and hence were not included for statistical analysis. Alternately, test entries were compared

with JL 24. Because of the year to year seasonal differences, seed yield data of 12 genotypes over 16 environments were subjected to combined analysis of variance separately for the years 2000 and 2001. The sum of squares was first partitioned into genotype, environment and GE interaction. Then, GE interaction was further partitioned by principal component analysis using AMMI model (Zobel *et al.*, 1988). The AMMI model is

$$Y_{ij} = u + g_i + e_j + \sum_{k=1}^{n} \lambda_k \alpha_{jk} \gamma_{ik} + R_{ij},$$

where Y_{ij} is the seed yield of the i^{th} genotype in the j^{th} environment; u is the grand mean; g_i is the mean of the i^{th} genotype minus the grand mean; e_j is the mean of the j^{th} environment minus the grand mean; λ_k is the singular value for the principal component analysis axis k; α_{jk} and γ_{ik} are the principal component scores for the principal component analysis axis k of the i^{th} genotype and j^{th} environment, respectively and R_{ij} is the residual. Statistical analysis was conducted using IRRISTAT software (IRRI, 2003).

Results and discussion

The AMMI ANOVA for seed yield showed that genotype and environment main effects and GE interaction were significant in 2000 and 2001 (Table 1). In 2000, 74.7% of the total sum of squares was attributed to environmental effects, 21.2% to GE interaction effects and only 4.1% to genotype effects. Similar trend was maintained in 2001 also, with higher environmental effects. A large sum of squares for environments indicated that the environments were diverse, with large differences among environmental means causing most of the variation in seed yield. Sum of squares for GE interaction was 5-6 times higher than that of genotypes, indicating substantial differences in genotypic response across environments.

AMMI analysis also showed that the first interaction principal component axis (IPCA 1) captured 36.7% and 31.9% of the interaction sum of squares in 2000 and 2001, respectively (Table 1). Similarly, second interaction principal component axis (IPCA 2) explained further 27.5% and 24.2% of the GE interaction sum of squares. The sum of squares for IPCA 1 and IPCA 2 cumulatively contributed 64.2% and 56.1% to the total GE interaction. Thus, the interaction of the 12 genotypes with 16 environments was best predicted by IPCA 1 and IPCA 2, as reported earlier (Gauch and Zobel, 1997; Casanoves *et al.*, 2005, Yan and Rajcan, 2002).

In AMMI biplots, the X-axes are the mean seed yields of genotypes over environments or the mean seed yields of environments over genotypes and the Y-axes are the genotypic or environmental IPCA 1 scores for 2000 and 2001 (Fig. 1a and 1b). The highest mean seed yield was recorded in TG 37A with a superiority of 15.4% over JL 24 (Fig. 1a). GPBD 4 and Dh 2000-1 showed 3% greater yield. In 2001 also, the highest mean seed was recorded in TG 37A with a superiority of 14.7% over JL 24 (Fig. 1b). Dh 2000-1, TG 38C and TG 38B registered increased mean seed yields of 8.9%, 7.1% and 7.0%, respectively.

Genotypes having near-zero/zero IPCA 1 scores indicate little or no interaction that means they have broader adaptability. Changes for the IPCA 1 scores explain interaction differences among genotypes. Based on the AMMI biplots, following three genotypic interactions could be illustrated (Fig. 1a and 1b):

In 2000, genotypes TG 37A, K 1268, TNAU 262 and TNAU 325 with near-zero interaction scores, did not interact much with environments and therefore their rank orders were relatively stable. Among these, only TG 37A had higher yield than JL 24. In 2001, TG 37A and TNAU 262 had near-zero IPCA 1 scores and hence are broadly adapted. Further, TG 37A also recorded higher mean seed yield than JL 24. It is pertinent to emphasize that 2000 and 2001 biplots clearly indicated TG 37A was highly productive with wider adaptability in rainy season.

Large positive interaction score in 2000 was recorded by GPBD 4 followed by JL 24 and K 1271, while in 2001, it was with TG 38C followed by Dh 2000-1, TG 38B, TG 36A and K 1271.

Large negative interaction score in 2000 was noted by TG 38C followed by TG 38B, Dh 2000-1, TNAU 266 and TG 36A. In 2001, GPBD 4 had the highest negative interaction score, followed by JL 24, TNAU 266, TNAU 325 and K 1268. Further, it is interesting to note that IPCA 1 scores for GPBD 4 and JL 24 were positive in 2000 and negative in 2001 and vice-versa in the case of TG 38C, TG 38B and Dh 2000-1 (Fig.1 a and 1 b). Thus, these genotypes were adapted to different environments and their relative ranking orders vary greatly with environments and hence were narrowly adapted.

By using ANOVA, superior genotypes with top three ranks like TG 37A, GPBD 4 and Dh 2000-1 in 2000 and TG 37A, Dh 2000-1 and TG 38C in 2001 respectively were identified. Though these genotypes were productive, AMMI analysis could classify these based on adaptation as TG 37A was broadly adaptable and rest with narrow adaptation. On the contrary, TNAU 325, K 1268 and TNAU 262 ranked 7, 8 and 9th in 2000 and TNAU 262 ranked 12th in 2001 (lower productivity) were widely adaptable due to their lower interactions. Thus, it is highly desirable to have not only productive but widely adaptable genotype which is realizable through AMMI analysis.

AMMI biplots for locations indicated smaller environmental interaction scores for Kadiri and Vriddhachalam with larger main effect in 2000 (Fig. 1 a) and smaller environmental interaction scores for Hanumangarh and Digraj but with smaller main effect in 2001 (Fig. 1 b). In both the years, Jhargram, Junagadh and Udaipur recorded larger main

effects having different (positive or negative) interaction with genotypes, while Khargone, Akola and Jalgaon recorded smaller main effects. Rest of the locations had varied main effects and interaction scores. Of the 16 locations, location means of only Junagadh, Udaipur, Jhargram, Aliyarnagar, Vriddhachalam and Dharwad were greater than the grand mean of the trial. Among thes locations, AMMI analysis identified Udaipur (belong t Zone II) and Aliyarnagar (Zone V) were with large Junagadh (Zone II), Jhargram (Zone IV) and Dharwa (Zone V) with moderate and Vriddhachalam (Zone V) wit least environmental interaction scores.

Table 1 AMMI analysis of variance for seed yield (kg/ha) during rainy season 2000 and 2001

Source	df	2000		2001	
		Sum of squares	%	Sum of squares	%
Genotype (G)	11	2090090**	4.1	1300460**	1.5
Environment (E)	15	37684100**	74.7	75530800**	87.5
G x E	165	10659910**	21.2	9472310**	11.0
IPCA 1	25	3910730**	36.7	3020850**	31.9
IPCA 2	23	2936170**	27.5	2295680**	24.2
IPCA 3	21	1146680*	10.8	1503310**	15.9
IPCA 4	19	845820*	7.9	1194910**	12.6
Residual	77	1820510	17.1	1457560	15.4
Total	191	50434100		86303570	

* and ** indicate significance at P = 0.05 and 0.01

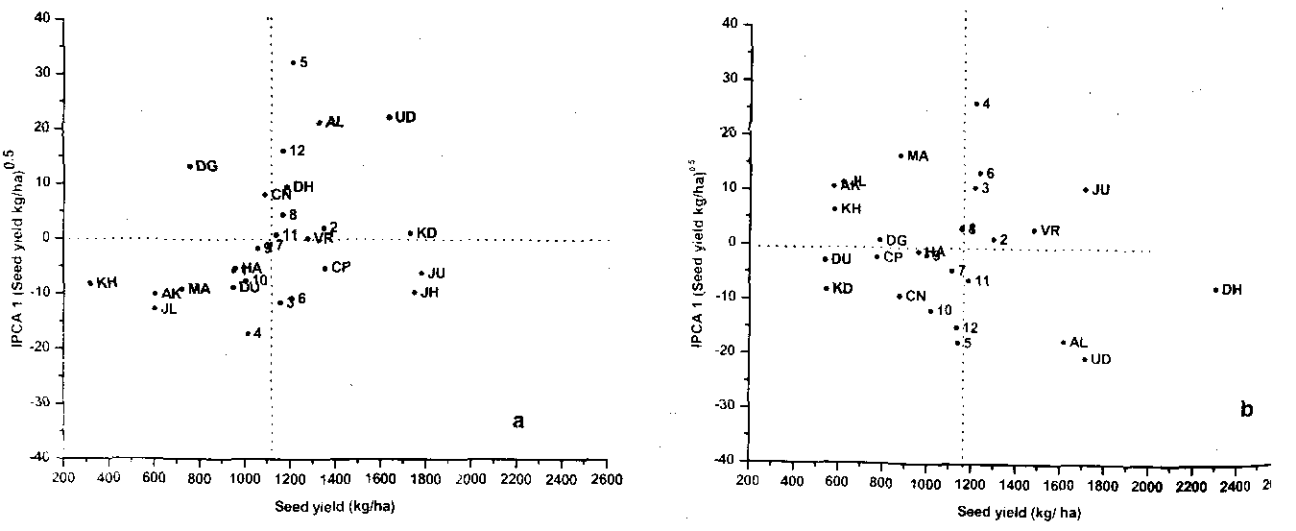

Fig. 1 Biplot of 1_2 genotypes and 16 environments for seed yield (kg/ha) during rainy season, 2000 (a) and 2001 (b). Grand mean yield indicated by vertical and zero-interaction score by horizontal dotted line

Genotypes: TG 36A (1); TG 37A (2); TG 38B (3); TG 38C (4); GPBD 4 (5); Dh 2000-1 (6); K 1268 (8); TNAU 262 (9); TNAU 266 (10); TNAU 325 (11) and JL 24 (12)

Environments: Durgapura (DU), Hanumangarh (HA), Mainpuri (MA), Junagadh (JU), Udaipur (UD), Akola (AK), Khargone (KH), Jalgaon (JL), Chiplima (CP), Jhargram (JH), Aliyarnagar (AL), Chingtamani (CN), Dharwad (DH), Digraj (DG), Kadiri (KD) and Vriddhachalam (VR)

The genotypic performance would be better when genotypes were grown in those environments whose interaction scores are large and of similar sign and would be poorer when their interaction scores are large and opposite sign (Ebdon and Gauch, 2002). At Udaipur in 2000 and 2001, GPBD 4 and TG 38C recorded greater and poorer seed yields, respectively, since their combination yielded the largest positive and negative interaction scores (Fig. 1a and 1b). Similarly, at Aliyarnagar during 2000, GPBD 4 and TG 38C showed superior and inferior performance, respectively. Thus, AMMI analysis helped in understanding the specific or broader GE interactions among 12 genotypes and 16 environments.

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Character association and path analysis for morphophysiological traits in groundnut, *Arachis hypogaea* L.

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Abstract

The correlation coefficients among 13 morphological, physiological and yield attributes with their path effects towards pod yield were investigated in 28 F_1s of groundnut during *rabi* 2002. Consistent and highly significant positive association of harvest index, number of well filled and mature pods/plant and kernel yield/plant with pod yield/plant indicated that they could be used as selection criteria for higher pod yield. Path coefficient analysis revealed high positive direct effects of kernel yield/plant followed by specific leaf nitrogen, root length, shelling per cent and number of well filled and mature pods/plant on pod yield indicating that these characters should be given greater emphasis while making selections for higher pod yield.

Key words: Character association, path coefficient, groundnut

Introduction

Information on the phenotypic and genotypic inter-relationships of pod yield in groundnut with its component characters and also among the characters themselves would be very much useful to the plant breeder in developing an appropriate breeding strategy. But yield is a complex character and is influenced by a number of traits which in turn are interrelated. The interdependence of these characters will influence pod yield either directly or indirectly and as a result the information obtained on the association of these traits becomes unreliable. Therefore, path coefficient analysis permits the separation of direct effects from indirect effects and gives more realistic relationship of the characters and helps in effective selection. Hence, the present study is aimed to analyse and determine the characters having greater inter relationship with pod yield utilising the correlation coefficients and path analysis.

Materials and methods

The material consisted of 28 F_1 s (direct crosses) derived out of 8 x 8 diallel mating system involving eight parents *viz.*, TIR - 46. JUG-37, ICR-45, TIR-10, K-134, JAL-6, JUG-43 and JL-24. The experiment was laid out in a Randomized Block Design with two replications during *rabi*, 2002. Each plot consisted of three rows of 4 m length and the plant to plant and row to row distance was maintained at 15 cm and 30 cm, respectively. All the recommended agronomic practices were adopted to raise good crop. Observations were recorded on 10 randomly chosen competitive plants from each treatment in each replication. At 75 days after sowing 3rd healthy leaf from the apex on the main stem of each of the parent and F_1s selected at random from each replication used to record data on four characters *viz.*, SPAD chlorophyll meter reading (SCMR), specific leaf nitrogen (SLN), specific leaf area (SLA) and per cent reduction of Fv/Fm (Fv/Fm). Leaf thickness was measured using screw gauge. Fv/Fm ratio is a measure of efficiency with which light is utilized for photosynthesis. Upon treatment Fv/Fm ratio declines indicating photo-inhibitory damage due to heat stress Similarly at maturity data was recorded for nine characters (Table 1). Standard procedures were followed for computing correlations and path analysis.

Results and discussion

Pod yield/plant had significant positive association with harvest index (r_p = 0.315, r_g = 0.310), number of well filled and mature pods/plant (r_p = 0.565, r_g = 0.616) and kernel yield/plant (r_p = 0.657, r_g = 0.687) (Table 1).These characters can be considered as criteria for selection for higher yield as they are mutually and directly associated with pod yield/plant. Similar results have been reported by Johar Singh and Mohinder Singh (2001). It had significant negative association with per cent reduction of Fv/Fm (r_g = -0.445) and shelling per cent (r_g = -0.313). Chauhan and Senboku (1997) while studying heat tolerance in groundnut by chlorophyll fluorescence technique, observed a strong positive correlation between chlorophyll concentration and chlorophyll fluorescence. They observed that Fv/Fm ratio decreased with increasing temperature stress. Therefore, lesser the per cent of reduction of Fv/Fm more will be the ability of plant to tolerate to high temperature stress and resulting in increased pod yield even under drought conditions.

Kernel yield/plant exhibited significant and positive association with specific leaf nitrogen (r_g = 0.417), harvest index (r_p = 0.414, r_g = 0.483), oil per cent (r_g =

0.286) and sound mature kernel per cent (r_p = 0.644, r_g = 0.666). Similar results have been obtained by Jayalakshmi *et al.*, (2000) in groundnut. The relationship of kernel yield/plant with SPAD chlorophyll meter reading (r_p = -0.268, r_g = -0.348), per cent reduction of Fv/Fm (r_g = -0.534) and root length (r_g = -0.407) was significant and negative.

SPAD chlorophyll meter reading established a significant and positive relationship with specific leaf nitrogen (r_g = 0.296), per cent reduction of Fv/Fm (r_g = 0.390), root length (r_g = 0.307), shell thickness (r_g = 0.577) and sound mature kernel per cent (r_g = 0.275), while it's association with harvest index (r_g = -0.4720) was significant and negative. Wright *et al.* (1994) reported that SCMR and SLN considered to be an indicator of leaf chlorophyll content and hence CO_2 assimilation capacity. Increase in SCMR and SLN is associated with higher CO_2 assimilation and thereby increase pod yield even under moisture stress conditions. Specific leaf nitrogen exhibited significant positive association with specific leaf area (r_p = 0.266, r_g = 0.279), per cent reduction of Fv/Fm (r_p = 0.378, r_g = 0.438), shell thickness (r_p = 0.327, r_g = 0.331) and sound mature kernel per cent (r_p = 0.474, r_g = 0.540). Specific leaf area had significant positive association with harvest index (r_g = 0.285). Anuradha (1995) correlated the differences in photosynthetic rates with genotypic differences in SLA in many crop species. Peanut genotypes with low SLA had more photosynthetic machinery and the greater potential for assimilation of carbondioxide per unit leaf area. The differences in photosynthetic rates were closely associated with leaf thickness in other legumes. Leaves with high SLW (inverse of SLA) were cooler under a given radiation load due to higher stomatal conductance resulting in more evaporative cooling (Gupta *et al.*, 1989). High stomatal conductance was also shown to be negatively correlated with SLA in cotton(Bhardwaj *et al.*, 1986). Based on many experiments, over a wide range of environments and cultivars it was concluded that SLA was closely and negatively correlated with water use efficiency and positively correlated with carbon isotope discrimination. This highlights the possibility of using SLA as a selection index for high water use efficiency (Nageswara Rao and Wright ,1994). Per cent reduction of Fv/Fm had significant negative association with harvest index (r_g = -0.338) and number of well filled and mature pods/plant (r_g = -0.398).

Root length had significant positive association with shell thickness (r_p = 0.349, r_g = 0.380) and significant negative association with oil per cent (r_p = -0.355, r_g = - 0.490). Harvest index showed significant and positive association with number of well filled and mature pods per plant (r_p = 0.428, r_g = 0.433. Similar results have been reported by Jayalakshmi *et al.*, (2000).

Table 1 Phenotypic (P) and genotypic (G) correlation coefficients for physiological, yield and yield component

Character		SLN	SLA	Fv/Fm	RL	HI	ST	OP	SP	SMKP	PPL	KY	PY
SCMR	P	0.219	0.007	0.169	0.132	-0.312*	0.403**	-0.024	-0.133	0.159	-0.119	-0.268*	-0.160
	G	0.296*	0.085	0.390*	0.307*	-0.472**	0.577**	-0.116	-0.226	0.279*	- 0.006	-0.348**	-0.112
SLN	P		0.266*	0.378**	0.052	-0.012	0.327*	0.163	0.128	0.474**	-0.056	0.0226	-0.019
	G		0.279*	0.438**	0.056	-0.017	0.331*	0.199	0.166	0.540**	-0.136	0.417**	-0.026
SLA	P			0.027	-0.118	0.253	0.074	-0.019	0.080	-0.004	0.114	-0.032	0.081
	G			0.029	-0.187	0.285*	0.076	-0.020	0.081	-0.005	0.221	-0.053	0.107
Fv/Fm	P				-0.119	-0.195	0.023	0.087	0.210	0.089	-0.151	-0.242	-0.245
	G				-0.152	-0.338*	0.024	0.056	0.247	0.103	-0.398**	-0.534**	-0.445**
RL	P					-0.189	0.349**	-0.355**	-0.155	-0.015	-0.113	-0.150	-0.008
	G					-0.245	0.380**	-0.490**	-0.208	-0.013	-0.258	-0.407**	-0.126
HI	P						-0.165	0.083	0.031	0.047	0.428**	0.414**	0.315*
	G						-0.209	0.070	0.035	0.057	0.433**	0.483**	0.310*
ST	P							-0.067	-0.259	0.221	0.075	-0.047	-0.009
	G							-0.074	-0.315*	0.239	0.095	-0.120	-0.036
OP	P								-0.048	0.055	-0.038	0.151	-0.119
	G								-0.049	0.098	-0.166	0.286*	-0.084
SP	P									0.386**	-0.146	0.080	-0.084
	G									0.504**	-0.259	0.088	-0.313*
SMKP	P										-0.070	-0.206	-0.049
	G										-0.287*	-0.124	-0.014
PPL	P											0.644**	0.565**
	G											0.666**	0.616**
KY	P												0.657**
	G												0.657**

*,** Significant at 5% and 1 % levels of probability respectively
SCMR :SPAD chlorophyll meter reading; SLN: Specific leaf nitrogen; SLA: Specific leaf area;
Fv/Fm :Per cent reduction of Fv/Fm; RL: Root length; HI: Harvest index; ST: Shell thickness; OP: Oil per cent;
SP: Shelling per cent; SMKP: Sound mature kernel per cent; PPL: Number of well filled and mature pods per plant
KY: Kernel yield per plant; PY : Pod yield per plant

Table 2 **Path coefficients for pod yield in F_1s in groundnut**

Character	SCMR	SLN	SLA	Fv/Fm	RL	HI	ST	OP	SP	SMKP	PPL	KY
SCMR	-0.00.	0.032	0.001	-0.018	0.020	0.023	-0.068	-0.002	0.019	0.014	-0.029	-0.148
SLN	-0.001	0.146	0.025	-0.040	0.008	0.001	-0.055	0.011	-0.018	0.041	-0.013	-0.125
SLA	-0.000	0.039	0.094	-0.003	-0.101	-0.018	-0.013	-0.001	-0.011	-0.001	0.027	-0.017
Fv/Fm	-0.001	0.056	0.003	-0.016	-0.019	0.015	-0.004	0.006	-0.029	0.008	-0.036	-0.136
RL	-0.001	0.008	-0.011	0.013	0.156	0.012	-0.058	-0.025	0.022	-0.001	-0.027	-0.079
HI	0.001	-0.002	0.024	0.021	-0.026	-0.072	0.028	0.006	-0.005	0.004	0.103	0.227
ST	-0.001	0.048	0.007	-0.003	0.054	0.012	-0.168	-0.005	0.037	0.019	0.019	-0.025
OP	0.000	0.024	-0.002	-0.009	-0.055	-0.006	0.012	0.069	0.008	0.005	-0.009	0.084
SP	0.001	0.019	0.008	-0.022	-0.024	-0.002	0.044	-0.004	0.142	0.033	-0.035	0.041
SMKP	-0.001	0.069	-0.001	-0.009	-0.002	-0.003	-0.037	0.004	-0.055	0.086	-0.017	0.015
PPL	0.000	-0.008	0.011	0.016	-0.018	-0.031	-0.013	-0.003	0.021	-0.006	0.241	0.355
KY	0.001	-0.033	-0.003	0.026	-0.022	-0.209	0.008	0.011	-0.011	0.002	0.155	0.552

Residual effect : 0.4618 , Diagonal values (Bold) are direct effects

Shell thickness exhibited significant negative association with shelling per cent (r_g = -0.315) indicating that thin shelled genotypes would have higher shelling per cent. The association between shelling per cent and sound mature kernel per cent was significant and positive (r_p = 0.386, r_g = 0.504). Sharma and Varshney (1993) reported similar results in groundnut. Sound mature kernel per cent exhibited significant negative association with number of well filled and mature pods per plant (r_g =-0.287). This is in concurrence with the findings of Vasanthi *et al.*,(1998). Out of 13 characters studied (Table 2) kernel yield per plant exerted maximum positive direct effect on pod yield per plant which is in agreement with the results of Makhan Lal *et al.*, (2003). The direct effects of specific leaf nitrogen, specific leaf area, root length, oil per cent, shelling per cent, sound mature kernel per cent and number well filled and mature pods/plant on pod yield/plant was also positive. Number well filled and mature pods/plant and harvest index exerted high positive indirect effects through kernel yield/plant and contributed directly and positively to pod yield/plant. In case of harvest index negative direct effect was nullified by its positive indirect effect via specific leaf area, per cent reduction of Fv/Fm , shell thickness, number of well filled and mature pods/plant and kernel yield. When both direct and indirect positive contributions were considered, kernel yield/plant, harvest index, specific leaf nitrogen, root length, shelling per cent was proved to be an outstanding character influencing pod yield/plant in groundnut. Further, the residual factor was low which suggest that the variables chosen in the present study were sufficient to explain pod yield/plant. These findings are in agreement with the findings of Azad and Hamid (2000).

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Analysis of pod shattering and yield attributes in soybean, *Glycine max* (L.) Merrill

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Abstract

Pod shattering in soybean is one of the major lacunae that takes a heavy toll of the produce. Seven soybean varieties, representing high variation in pod shattering behaviour and their 21 F_1 crosses and six selected F_2 populations were grown to study combining ability, gene action and genetics of pod shattering and productivity related traits in soybean. The parents Bragg, Indira Soya-9 and JS-335 were found to be good general combiners for pod shattering and other important characters. Hybrids, JS-335 x Bragg and Indira Soya-9 x Bragg were found to have high yielding ability along with considerable pod shattering resistance, thus these crosses give scope for overall improvement. Segregation pattern of pod shattering was very complex in F_2 generation and shows quantitative response. The F_2 segregation pattern revealed the possibility of developing shattering resistant genotypes by crossing two resistant parents.

Key words: Soybean, pod shattering, combining ability, gene action, genetics

Introduction

Pod shattering in soybean is a disadvantage, which leads to serious yield losses. Pod shattering refers to the opening of mature pods along with dorsal or ventral sutures and dispersal of seed as the crop reaches maturity as well as during harvesting. Seed losses of 50 to 100% are often associated with pod shattering in susceptible varieties and delayed harvesting after maturity (Anonymous, 2001). Among the reasons for pod shattering, the genetic endowment of the variety plays an important role on the overall expression of pod shattering (Tiwari and Bhatnagar, 1991).

Materials and methods

The seven soybean lines *viz.*, JS-335, JS 80-21, Indira Soya-9, Bragg, Birsa Soya-1, Monetta and PK-1029, representing variation in pod shattering were crossed in diallel fashion excluding reciprocals during *kharif*, 2003 at Oilseed Research Area of Indira Gandhi Agricultural University, Raipur. All the lines and resultant 21 crosses were grown in Randomized Complete Block Design with three replications during *kharif*, 2004. Each entry was grown in single row of 3 m length with spacing of 40 cm x 10 cm. Observations were recorded on five random plants in each entry for 19 quantitative characters. The data was analyzed by using Griffing's Method-2 and Model-1 (Griffing, 1956). The pod shattering was recorded using laboratory method (Tiwari and Bhatnagar, 1991) in which, from each entry a sample of 25 pods were collected at maturity and kept in oven at 40°C for seven days. On the seventh day the number of shattered pods were counted and expressed in the percentage. The angular transformed values of pod shattering percentage were used for statistical analysis. The F_2 generation (advanced from F_1 to F_2 during *rabi*/summer 2003-04) of six selected crosses along with parents were also grown during *kharif*, 2004. The pod shattering percentage of individual plants of six F_2 populations were classified using frequency distribution.

Results and discussion

Analysis of variance of combining ability revealed that mean squares due to gca and sca were highly significant for all the characters, indicating the importance of both additive and non-additive genetic components of variation for controlling the traits. The general combining ability effect of parents for the characters studied (Table 1) indicated that for pod shattering resistance, Bragg was the best general combiner followed by JS-335, Indira Soya-9 and PK-1029. Tiwari and Bhatnagar (1991) also reported that Bragg was good general combiner for pod shattering resistance. Indira Soya-9 and Bragg were found to be good general combiners for seed yield, pods/plant and clusters/plant. Thus these parents should be used in hybridization program to impart pod shattering resistance along with high yielding potential in soybean. As none of the parents was found to be good combiner for all the characters, the procedure suggested by Arunachalam *et al.* (1984) was employed to ascertain the overall status of parent with respect to number of component characters. On overall character basis (Table 1), Bragg, Indira Soya-9 and JS-335 were considered as good general combiners, whereas JS 80-21, Birsa Soya-1, Monetta and PK-1029 were poor combiners.

The hybrids, those had given significantly higher yield than local check Indira Soya-9 are presented in Table 2. Hybrid, Indira Soya-9 x Bragg was the highest yielder and found

to be at par with JS 80-21 x Indira Soya-9, Indira Soya-9 x Monetta, Bragg x Birsa Soya-1 and Bragg x Monetta. These crosses exhibited higher *per se* performance, highly significant *sca* effects for yield and having high overall *sca* effect. Thus these hybrids can be considered as promising one and should be selected in breeding program to exploit yield potential in soybean. In general it was observed that parents, Indira Soya-9 and Bragg, which are categorized as good general combiners for seed yield had given better hybrids with other parents. Thus, it appears that for getting good hybrid combinations for yield, *gca* of parent is very important. Kaw and Menon (1981), Halvankar and Patil (1993) and Gadag *et al.* (1999) reported that superior combinations for seed yield, involved at least one parent with high *gca*.

The performance of 7 parents and their 21 crosses in F_1 generation with regards to pod shattering are presented in Table 3. Among the parents, Bragg (3.68%) found to be highly resistant to pod shattering followed by JS-335 (14.24%) and Indira Soya-9 (16.32%), whereas, on the other hand Monetta (86.24%) was found to be highly susceptible to pod shattering. Parents JS 80-21 (45.92%) and Birsa Soya-1 (36.80%) were found to be moderately susceptible, while, PK-1029 registered 30.72% pod shattering. Tiwari and Bhatnagar (1993) also reported that Bragg possessed the high degree of resistance to pod shattering, while Monetta was highly susceptible one. Among the crosses studied, JS-335 x Bragg was found to have lowest pod shattering percentage, followed by Indira Soya-9 x Bragg, JS-335 x Indira Soya-9 and Bragg x PK-1029. These four selected crosses have high x high *gca* status of parents involved in developing resistance to pod shattering. The segregation pattern (Fig. 1) of cross involving highly resistant (HR) x highly susceptible (HS) (Bragg x Monetta) parents showed a continuous distribution of pod shattering per cent over all the class intervals. Similar trend was also observed for other crosses studied in F_2 generation. The wide range of F_2 segregants in all the class intervals may be due to presence of dominant genes in the susceptible variety that masks the recessive resistant genes. Thus, the segregation pattern of pod shattering was very complex in F_2 generation and shows quantitative response. The frequency of most desirable plants (up to 10 %) in F_2 generation was highest in the cross of Indira Soya-9 x Bragg (56 plants), followed by JS-335 x Bragg (53), while total number of desirable segregants (up to 20%) were highest in JS-335 x Bragg (136 plants) followed by Indira Soya-9 x Bragg (134 plants). Thus both the cross involving resistant x highly resistant parents for pod shattering had given highest number of desirable segregants, indicating the possibility of development of highly shattering resistant genotypes in future soybean-breeding program. The chances of further segregation of most desirable plants were less as they had most of recessive genes, which do not segregate in further generation. In the present study Indira Soya-9 x Bragg was highest yielder and rank second for pod shattering resistance while, JS-335 x Bragg exhibited lowest pod shattering and was found at par with Indira Soya-9 for yield performance in F_1 generation. Thus these two crosses (JS-335 x Bragg and Indira Soya-9 x Bragg) give a scope for overall improvement.

Table 1 General combining ability effects of parents for pod shattering and overall *gca* status for 19 characters in soybean

Character	JS 335	JS 80-21	Indira Soya-9	Bragg	Birsa Soya-1	Monetta	PK 1029	SE (gi)
Pod shattering	-5.14**	3.59**	-4.41**	-8.08**	1.57**	13.30**	-0.84**	0.27
Overall *gca* status	H	L	H	H	L	L	L	

**=Significant at 1% level; SE(gi) = Standard error for general combining ability effects; H = High; L = Low

Table 2 Hybrids with better performance for yield with *sca* values, overall *sca* values and *gca* status of parents involved

Crosses	Yield (g/plant)	*sca* effect for yield/plant	Overall *sca* effect	*gca* effect of parents	
				Female	Male
Indira Soya-9 x Bragg	25.41	3.01**	H	H	H
JS 80-21 x Indira soya-9	24.85	5.34**	H	L	H
Indira Soya-9 x Monetta	24.24	4.58**	H	H	L
Bragg x Birsa Soya-1	24.10	5.75**	H	H	L
Bragg x Monetta	23.17	5.21**	H	H	L
JS-335 x Indira Soya-9	21.50	0.87	H	L	H
Bragg x PK-1029	20.91	3.71**	H	H	L
Indira Soya-9 x PK-1029	20.56	1.68	H	H	L
JS-335 x Birsa Soya-1	20.41	3.83**	H	H	L
Indira Soya-9 ©	16.87				

** = Significant at 1% level; **H = High; L = Low**

Table 3 Performance of parents and their crosses for pod shattering in F_1 generation with *gca* status of parents involve

Parent / Cross	Pod shattering percentage		
	Parent	F_1	*gca* effect of parents
JS-335	14.24	-	H
JS 80-21	45.92	-	L
Indira Soya-9	16.32	-	H
Bragg	3.68	-	H
Birsa Soya-1	36.80	-	L
Monetta	86.24	-	L
PK-1029	30.72	-	H
JS-335 x JS 80-21	-	38.29	H X L
JS-335 x Indira Soya-9	-	16.57	H X H
JS-335 x Bragg	-	12.19	H X H
JS-335 x Birsa Soya-1	-	30.29	H X L
JS-335 x Monetta	-	65.71	H X L
JS-335 x PK-1029	-	25.33	H X H
JS 80-21 x Indira Soya-9	-	38.19	L X H
JS 80-21 x Bragg	-	33.52	L X H
JS 80-21 x Birsa Soya-1	-	44.38	L X L
JS 80-21 x Monetta	-	79.81	L X L
JS 80-21 x PK-1029	-	41.52	L X H
Indira Soya-9 x Bragg	-	14.48	H X H
Indira Soya-9 x Birsa Soya-1	-	35.24	H X L
Indira Soya-9 x Monetta	-	62.67	H X L
Indira Soya-9 x PK-1029	-	26.86	H X H
Bragg x Birsa Soya-1	-	29.90	H X L
Bragg x Monetta	-	68.76	H X L
Bragg x PK-1029	-	21.14	H X H
Birsa Soya-1 x Monetta	-	76.57	L X L
Birsa Soya-1 x PK-1029	-	35.62	L X H
Monetta x PK-1029	-	70.29	L X H

L = Low
H = High

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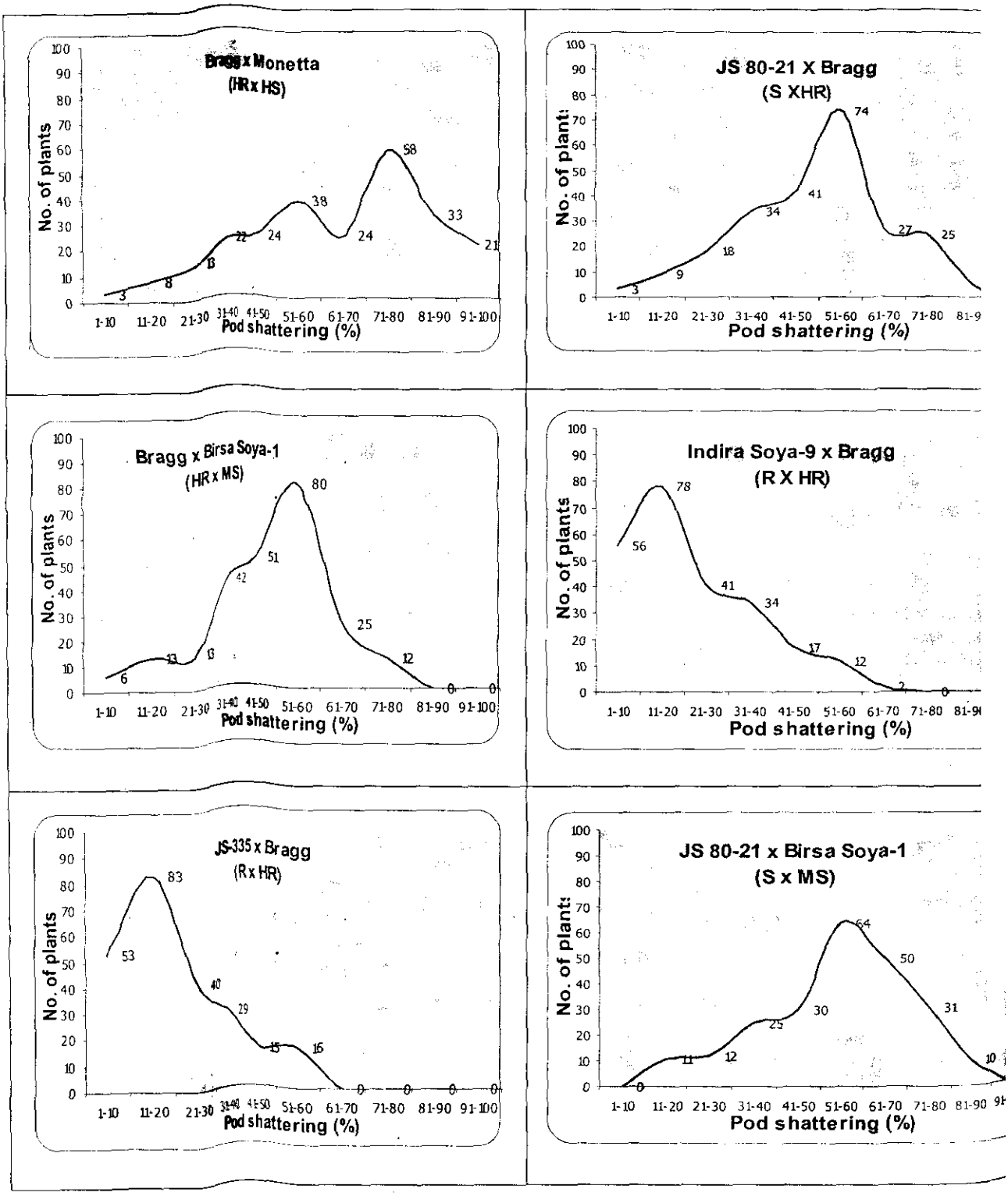

Fig. 1. Segregation pattern of pod shattering in F_2 generation of soybean

HR = Highly resistant R = Resistant; MS = Moderately susceptible; S = Susceptible; HS = Highly susceptible

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Evaluation and characterisation of elite germplasm of Indian mustard, *Brassica juncea* (L.) Czern & Coss.

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Abstract

One hundred twelve germplasm accessions of Indian mustard *Brassica juncea* were evaluated for 15 agro-morphological and quality traits, with three checks (PCR 7, BIO 902 and RH 30). The maximum variability was observed for secondary branches/plant followed by 1000-seed weight whereas, least variability was observed for days to maturity followed by oil content. Promising donors were identified for various economic traits, which can be further used for future breeding programme. Genotype RAURD 9612 was found to be one of the useful donors for siliqua length, main shoot length and seeds/siliqua. Genotype RN 553 was found as desirable donor for main shoot length and 1000-seed weight. Genotype PRO 2103 was found superior for primary branches, more number of siliquae on main shoot. Harvest index were recorded maximum in the genotype, ORT (m) 7-1, highest 1000-seed weight and seeds/siliqua were recorded in genotype YRS 67 and HNS 9605 respectively. The seed yield had positive and significant correlations with plant height, main shoot length, siliquae on main shoot, primary and secondary branches/plant. Hence selection for the higher values of these traits will be desirable to increase seed yield. Characterization of promising genotypes having high oil content and 1000-seed weight was also undertaken.

Key words: Indian mustard, germplasm, variability, donors, evaluation, characterisation

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss] is an annual species belonging to family *Brassicaceae* and important amongst the cultivated oilseed *Brassica* species in India. *Brassicas* have narrow genetic base and variability available in present germplasm of rapeseed-mustard is limited to a few desired traits. Many of the germplasm lines possess desirable traits which are otherwise not available in cultivated oilseed *Brassica and* germplasm play an important role in crop improvement programme of rapeseed-mustard (Kumar *et al.*, 2004). Evaluation and characterization of germplasm is necessary in order to search for potential donors (Yadav *et al.*, 1997; Misra *et al.*, 2004). A number of rapeseed-mustard varieties have been developed by utilization of elite germplasm (Kumar *et al.*, 2004; Chauhan *et al.*, 2006). Therefore, in the present investigations, emphasis has been given to characterize germplasm for oil content and 1000- seed weight.

Materials and methods

Elite germplasm accessions were procured from various centers of AICRP (R-M) network during 2001 and 2002. These germplasm accessions were grown in an Augmented Design spaced 30 cm x 10 cm with three checks (PCR 7, BIO 902 and RH 30) at National Research Centre on Rapeseed-Mustard, Sewar, Bharatpur during *rabi* 2002-2003. These germplasm accessions were evaluated for 15 agro-morphological and quality traits *viz.*, initiation of flowering (days), 50% flowering (days), days to maturity, plant height (cm), primary branches, secondary branches, main shoot length (cm), siliquae on main shoot, siliqua length (cm), siliqua beak length (cm), seeds per siliqua, 1000-seed weight (g), harvest index (%), oil and protein content (%). The observations were recorded on randomly tagged five plants for different traits at appropriate growth stages. Protein and oil content were analyzed by Near Infrared Reflectance Spectroscopy (Dickey- John, Instalab 600). Range, mean, coefficient of variation and simple correlation coefficients were computed using standard statistical methods (Gomez and Gomez, 1984).

Results and discussion

Sufficient genetic variability was observed in the material under study (Table 1). Among the 15 traits studied, maximum variability was observed for secondary branches/plant followed by 1000-seed weight. The least variability was observed for days to maturity followed by oil content. Similar trend of genetic variation has also been reported by various other workers in oilseed *Brassica* (Yadav *et al.*, 1997; Kumar *et al.*, 2000; Chauhan *et al.*, 2000; Meena *et al.*, 2000).

Promising donors were identified for various economic traits (Table 2), which can be further used for future breeding programme. Genotype RAURD 9612 found to be

one of the useful donors for siliqua length, main shoot length and seeds/siliqua. Genotypes BIO (E) 2 and ORT (m) 7-1 were identified for early as well as 50% flowering. Further, genotype RN 553 was recorded as desirable donor for main shoot length and 1000-seed weight. Genotype PRO 2103 had highest number of primary branches and siliquae on main shoot. Harvest index was recorded to be maximum in the genotype ORT (m) 7-1. The highest 1000-seed weight and seeds/siliqua were recorded in genotype YRS 67 and HNS 9605, respectively.

Seed yield had positive and significant correlations with plant height, primary branches/plant, secondary branches/plant, main shoot length and siliquae on main shoot (Table 3). These findings are in agreement with Reddy (1991), Kachroo et al. (1997) and Misra *et al.* (2004). Therefore, selection of these characters will be helpful in increasing seed yield. Seed yield had non significant correlation for 10 morphological traits. However, it had negative correlation with oil content, siliqua beak length and 50 % flowering. Others important traits such as siliquae on main shoot had positive correlated with plant height, main shoot length and 1000 seed weight; in addition to this, 1000 seed weight had positively correlated with main shoot length. While, oil content had non- significant correlated with all the traits. Significantly negative correlations of 50% flowering with main shoot length, plant height and harvest index were observed. The associations between the yield related attributes revealed the mutual relationship between two or more characters; therefore, it is an important parameter for taking a decision regarding the selection and in formulation of breeding programme.

There was less variability for oil content per se in Indian mustard. The maximum oil content i.e. 43.4 % is reported in BPR 171. The promising accessions with more than 42% oil content were BPR 171, JGM 9011, ORT (m) 7-1, HUM 9903, JGM 01-11, YET 17, JGM 9005, RAURD 9621, PRO 2001 and HUM 9964 (Table 4). There are several bold seeded genotypes present in the available gene pool. The maximum 1000- seed weight (7.5 g) was recorded in genotype YRS 67. High 1000- seed weight (>6.5 g) were recorded in YRS 67, YRN 8, RN 553, RH 9304, YET 17, RN 518, MAHON 8 and RK-01-01. These promising genotypes having high seed weight were also characterized for various agromorphological traits (Table 5). These genotypes can be utilized in genetic enhancement of Indian mustard.

The promising accessions can be used directly for hybridization and other breeding strategy related to genetic improvement. It may also be concluded that seed yield had positive and significant correlations with plant height, primary branches/plant, secondary branches/plant, main shoot length and siliquae on main shoot and it had negative correlation with oil content, siliqua beak length and 50 % flowering. Therefore these characters should be considered for seed yield improvement in mustard breeding programmes.

Table 1 Variability in some agro-morphological traits in Indian mustard

Character	Range	Mean ± SEm	CV (%)	Mean values of checks		
				PCR 7	BIO 902	RH 30
Initiation of flowering (days)	34.0-99.0	51.9± 0.8	15.3	57.0	48.5	48.4
50 % flowering (days)	47.0-116.0	61.8± 0.9	14.5	66.1	57.1	56.4
Plant height (cm)	61.4-202.8	163.3± 0.7	11.4	187.4	162.5	160.4
Primary branches / plant	3.6-8.8	6.2± 0.1	19.2	6.6	6.1	5.8
Secondary branches / plant	1.0-17.6	10.4± 0.3	35.7	11.4	11.7	10.8
Main shoot length (cm)	21.4-88.0	67.6± 0.9	15.1	72.0	72.1	75.0
Siliqua on main shoot	20.4-54.8	41.6± 0.5	12.8	43.6	43.5	46.0
Maturity (days)	138.0-159.0	148.4± 0.2	1.7	149.6	147.2	149.8
Siliqua length (cm)	3.37-6.1	4.8± 0.0	11.3	5.5	5.1	5.1
Siliqua beak length (cm)	0.63-1.7	1.07± 0.0	12.7	1.08	1.04	1.09
Harvest index (%)	16.6-37.5	28.5± 0.3	13.9	23.7	27.8	28.7
Seeds / siliqua	10.6-20.2	14.3± 0.1	9.9	14.5	13.3	13.7
1000-seed weight (g)	2.6-7.5	4.9± 0.1	20.9	5.2	6.3	6.1
Protein content (%)	19.2-22.9	20.6± 0.0	3.3	20.6	20.2	20.6
Oil content (%)	37.4-43.4	40.3± 0.1	3.1	40.1	39.0	39.1

Table 2 Promising accessions of Indian mustard

Character	Indian mustard accessions
Primary branches/plant	≥ 6.6: BIO 322-95, JGM01-15, PAB 9534, RGN 55, PRO 2103
Main shoot length (cm)	≥75.2: NDR 2004, PR 9806, RAURD 9612, RK 01-04, RN 553
Siliquae on main shoot	≥46.0: JS 10, MJ 234, PRO 2103, PWR 9541, RGN 42
Siliqua length (cm)	≥ 5.5: DHR 9618, HUM 0003, NDR 2004, PR 9801, RAURD 9612
Seeds per siliqua	≥14.5: DHR 9618, HNS 9605, PBR 210, RAURD 9612, RK 2003
1000-seed weight (g)	≥7.0: RH 9904, RN 553, YET 17, YRN 8, YRS 67
Oil content (%)	≥42.5: BPR 171, JGM 01-11, JGM 9011, HUM 9903, ORT (m)7-1, YET 17

Table 3 Correlations among the different agro-morphological traits in Indian mustard germplasm

Character	Initiation of flowering	50 % flowering	Plant height	Primary branches/ plant	Secondary branches/ plant	Main shoot length	Siliquae on main shoot	Days to maturity	Siliqua length	Siliqua beak length	Harvest index	Seeds/ siliqua	1000-seed weight	Protein content	Oil content
50 % flowering	0.89*														
Plant height	0.35*	0.35*													
Primary branches	0.33*	0.30*	0.42*												
Secondary branches	-0.05	-0.11	0.27*	0.46*											
Main shoot length	-0.22	-0.33*	0.29*	-0.13	0.23										
Siliquae on main shoot	-0.15	-0.20	0.35*	0.10	0.24	0.57*									
Days to maturity	0.48*	0.59*	0.54*	0.36*	0.15	-0.05	0.06								
Siliqua length	0.09	0.09	0.28*	0.17	0.06	0.13	0.18	0.24							
Siliqua beak length	-0.01	-0.04	-0.24	-0.20	-0.36*	-0.05	-0.13	-0.13	0.00						
Harvest index	-0.21	-0.24	-0.35*	-0.24	-0.25	0.01	0.07	-0.16	-0.09	0.06					
Seeds/siliqua	0.18	0.33*	0.11	0.15	0.04	-0.03	0.06	0.17	0.29*	-0.15	-0.12				
1000-seed weight	-0.14	-0.25	0.13	-0.08	-0.11	0.49*	0.27*	0.03	0.18	0.17	0.25	-0.20			
Protein content	0.09	0.06	0.02	0.17	0.17	-0.03	0.00	0.06	-0.01	-0.16	0.03	0.03	-0.11		
Oil content	-0.09	0.02	-0.05	-0.08	-0.10	-0.17	-0.07	0.00	0.03	0.06	0.09	0.09	-0.13	-0.19	
Seed yield	0.03	-0.07	0.35*	0.36*	0.62*	0.42*	0.43*	0.12	0.13	-0.19	0.07	0.01	0.25	0.12	-0.05

Table 4 Characterisation of promising accessions of Indian mustard having high oil content (>42%)

Genotype	Oil Content (%)	Initial flowering (days)	50 % Flowering (days)	Plant Height (cm)	Primary Branches/ plant	Secondary Branches/ plant	Main shoot Length (cm)	Siliquae/ main shoot	Days to maturity	Siliqua length (cm)	Siliqua beak length (cm)	Harvest index	Seeds/ siliqua	1000-seed weight (g)	Protein content (%)
BPR 171	43.4	54	65	163	6		3	8	150	4.3	0.8	34.3	13	4.8	19.59
JGM 9011	42.8	37	54	150	5	9	61	46	145	4.2	1.0	26.7	15	4.0	20.42
ORT(m) 7-1	42.8	39	47	61	4	1	21	20	138	3.7	1.6	37.5	12	3.0	19.94
HUM 9903	42.6	47	60	163	6	10	73	40	152	4.2	1.2	28.8	14	5.5	19.83
JGM 01-11	42.5	47	57	174	7	13	72	45	148	4.9	1.0	27.9	14	4.2	20.55
YET 17	42.5	49	54	172	5	7	77	43	146	5.1	1.1	29.4	13	7.0	20.88
JGM 9005	42.3	49	59	189	8	14	65	39	150	4.7	1.0	29.0	15	3.4	21.7
RAURD 9621	42.3	50	64	171	6	8	60	40	149	5.0	1.0	28.5	15	3.8	21.26
PRO 2001	42.2	51	62	183	8	15	75	46	150	5.0	0.9	26.1	14	6.0	19.53
HUM 9964	42.1	57	65	169	6	9	63	39	151	5.1	1.0	32.5	15	4.7	20.68

Table 5 Characterisation of promising accessions of Indian mustard having highest 1000-seed weight (>6.5 g)

Genotype	1000-seed weight (g)	Initial flowering (days)	50 % flowering (days)	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Main shoot length (cm)	Siliquae/ main shoot	Days to maturity	Siliqua length (cm)	Siliqua beak length (cm)	Harvest Index (%)	Seeds/ siliqua	Protein content (%)
YRS 67	7.5	51	5	14	79	14	78.6	46.8	149	5.4	1.2	29.8	15	19.95
YRN 8	7.4	50	5	9	77	8.6	76.6	48.2	145	4.9	1.1	29.8	14	20.04
RN 553	7.3	55	4	4	87	3.8	87.4	40.6	146	4.2	1.7	27.5	13	20.7
RH 9304	7.1	50	5	4	70	4	69.8	43.4	149	4.7	1.1	34.3	13	20.69
YET 17	7.0	49	5	7	77	7.4	77	43	146	5.2	1.1	29.4	13	20.88
RN 518	6.9	49	6	4	72	4	71.8	39.4	148	5.1	1.1	27.7	14	19.86
MAHON 8	6.9	51	5	7	70	7.4	69.6	38.4	147	3.7	1.1	28.6	11	20.65
RK 01-01	6.7	55	6	13	69	13.4	67.8	48.4	151	5.5	1.1	31.3	13	21.16

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Genetic variability and path analysis for seed yield in yellow sarson, *Brassica rapa* var. yellow sarson

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Abstract

The magnitude of genetic variability and inter-relationships were studied for yield and its component characters in 80 germplasm lines of yellow sarson (*Brassica rapa* var. yellow sarson) in two environments. Higher estimates of phenotypic and genotypic coefficients of variability were recorded for seed yield/ plant and number of siliquae/plant in both the environments. High heritability along with high genetic advance were recorded for seed yield/plant, number of siliquae/plant and number of primary branches/plant. Correlation and path analysis revealed that plant height and number of siliquae/plant were the key yield contributing characters under study.

Key words: *Brassica rapa*, correlation, path analysis

Introduction

Yellow sarson (*Brassica rapa var. yellow* sarson) is an important *rabi* oilseed crop of north east India. Being a self-compatible and self-pollinated crop, pure line selection in genetically variable populations has been the main stay of breeding programme. Presence of variability is a pre-requisite for improvement in seed yield in any crop. Seed yield is polygenically controlled complex character and is determined by a number of yield components which are also quantitatively inherited. A knowledge of heritability and genetic advance of these characters indicates the scope of improvement through selection. Estimation of character association with seed yield and their direct and indirect effects on yield helps in the selection of desirable plant types. Therefore, the present investigation aims to examine the extent of genetic variability, and degree of association among different characters and to select superior lines for yield and related characters.

Materials and methods

The study was carried out with 80 diverse genotypes of yellow sarson including 73 local collections from different districts of eastern Uttar Pradesh, two lines from Jalna (Mahyco), three from NRCRM Bharatpur (Rajasthan) and one each from RAU, Dholi (Bihar) and Berhampore (W.B.). The experiment was conducted at Crop Research Station, Masodha (E_1) and Research Farm of Department of Genetics and Plant Breeding (E_2) of Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad in Randomized Block Design with three replications. Each plot consisted of single row of 3 m length with row to row and plant to plant spacing of 30 cm and 15 cm, respectively. Observations were recorded on five randomly selected competitive plants from each plot for 11 quantitative characters (Table 1). The data were statistically analyzed to estimate phenotypic and genotypic coefficient of variation, heritability and genetic advance. Phenotypic and genotypic correlations were calculated along with path coefficient analysis (Al-Jibouri *et al.*, 1958; Dewey and Lu, 1959).

Results and discussion

Analysis of variance revealed significant variability for all the characters under study. The coefficient of variability both at phenotypic and genotypic level were high for seed yield/plant followed by number of siliquae/plant, length of main raceme at E_1 and for seed yield/plant, followed by number of siliquae/plant, number of primary branches/plant, length of main raceme and plant height at E_2 (Table 1). Similar results were also reported by Singh *et al.* (1996) in yellow sarson, Saraswat (2002) and Mahla *et al.* (2003) in Indian mustard. Wide differences in the estimates of coefficients of variability at phenotypic and genotypic level for length of main raceme, number of primary branches/plant, number of siliquae/plant and 1000-seed weight at E_1 and days to 50 % flowering, length of main raceme, length of siliqua and plant height at E_2 indicated that these characters were highly influenced by environmental fluctuations.

The heritability estimates in broad sense were high for seed yield/plant, oil content and number of seeds siliqua in E_1 and for number of siliquae/plant, seed yield/plant and number of primary branches/ plant in E_2.

Oil content showed high heritability and low genetic advance at E_1 could be due to predominance of non-additive gene action (dominant or epistatic) and/or less genetic variability for this trait in the material. Incorporation of additional variability for oil content in the material would be rewarding. The characters such as seed yield/plant, number of siliquae/plant and number of primary

branches/plant in both the environments exhibited high heritability with high genetic advance indicating the predominance of additive gene effects and greater scope for improvement in these characters through selection. The high genetic advance coupled with moderate heritability for plant height and number of siliquae/plant at E_1 and 1000-seed weight at E_2 indicated the presence of both additive and non-additive gene effects and hence some promise for improvement in these traits through selection. Based on per se performance in both the environments, best three genotypes for different characters were identified (Table 2). It is evident from the table that outstanding genotypes for individual component characters were not simultaneously higher yielder. This revealed that yielding ability of the genotypes is dependent upon balanced combination of component characters. However, superior genotypes for individual component characters may be used as potential parents in combination breeding programme.

Correlation coefficients at genotypic and phenotypic levels showed that the number of siliquae/plant had positive and significant association with seed yield at E_1 as well as at E_2. Plant height showed positive and significant association with length of main raceme, number of primary branches/plant, number of siliquae/plant and seed yield/plant both at phenotypic and genotypic level at E_1. The associations of plant height with length of main raceme and primary branches/plant indicated that increase in plant height will accompany the positive improvement in these associated characters and will ultimately lead to increased seed yield. Length of main raceme expressed positive and significant association with number of siliquae/plant at E_1. This indicated that by increasing length of main raceme, number of siliquae/plant could be substantially increased leading to higher seed yield. The presence of substantial amount of variability in number of siliquae/plant and seeds/siliqua and their positive correlation with economic yield merit consideration for improvement of these characters. The estimates of genotypic and phenotypic correlation for different characters varied considerably in the two environments. The pattern of associations between characters was different under two environments, as also reported earlier by Masood *et al.* (1999), Shah *et al.* (2002) and Singh (2004) in *Brassica* species.

Path coefficient analysis (Table 3 and 4) revealed differing direction and magnitude of direct and indirect effects of component characters towards seed yield in two environments. On the basis of correlation studies it was inferred that higher expression of number of siliquae/plant in both the environments were indicative of higher seed yield. Number of siliquae/plant also showed highest direct effect on seed yield in both the environments.

Table 1 Genotypic and phenotypic coefficient of variability,, heritability (%) and genetic advance of different characters in E_1 and E_2

Character		Grand mean (x̄)SE	Range	Coefficient of variability		Heritability (broad sense)	Genetic advance	Genetic advance in % mean
				Phenotypic	Genotypic			
Days to 50 % flowering	E_1	44.33 ± 1.55	40.66-49.00	5.16	2.88	31.20	1.47	3.31
	E_2	44.07 ± 2.03	38.33-49.00	6.21	2.57	17.2	0.97	2.20
Days to maturity	E_1	103.78± 2.47	100.00-117.33	3.39	1.73	26.1	1.89	1.82
	E_2	104.92 ± 2.13	101.00-111.00	2.98	1.64	13.3	1.95	1.86
Plant height (cm)	E_1	97.77 ± 6.17	55.13-124.50	14.85	12.68	72.9	21.81	22.31
	E_2	95.01± 13.00	55.13-119.50	18.23	7.18	15.5	5.54	5.83
Length of main raceme (cm)	E_1	46.90 ± 5.65	27.93-64.10	18.76	11.56	38.0	6.88	14.67
	E_2	46.22 ± 6.36	27.93-64.99	20.57	11.80	32.9	6.44	13.94
Number of primary branches/plant	E_1	7.39 ± 0.99	4.38-12.65	26.66	21.06	62.1	2.52	34.11
	E_2	7.30 ± 0.59	4.05-12.20	26.36	24.40	85.7	3.39	46.53
Number of siliquae/plant	E_1	86.14± 12.58	44.88-172.12	33.35	28.15	71.3	42.17	48.96
	E_2	71.68 ± 4.76	36.73-135.56	30.26	29.14	92.8	41.44	57.82
Number of seeds/siliqua	E_1	26.52 ± 1.23	16.43-39.46	12.97	11.64	80.5	5.70	21.51
	E_2	26.85 ± 1.36	21.50-32.77	10.56	8.53	65.3	3.81	14.21
Length of siliqua (cm)	E_1	5.77± 0.26	4.50-6.76	9.75	7.98	67.0	0.77	13.45
	E_2	5.79± 0.54	4.86-7.14	12.35	4.70	14.5	0.21	3.69
1000-seed weight (g)	E_1	3.22 ± 0.30	2.44-4.42	13.62	7.14	27.6	0.25	7.73
	E_2	3.14± 0.21	2.43-4.28	14.76	12.10	67.2	0.64	20.43
Oil content (%)	E_1	41.68 ± 0.57	37.60-44.06	3.93	3.54	81.3	2.74	6.59
	E_2	42.79± 0.80	39.37-45.69	3.30	2.36	51.0	0.48	3.47
Seed yield/plant (g)	E_1	7.56 ± 0.75	3.80-14.70	33.59	31.27	86.6	4.53	59.94
	E_2	6.16± 0.71	2.79-11.45	34.61	31.57	83.2	3.65	59.31

Table 2 Promising accessions of yellow sarson

Character	Yellow *sarson* accessions
Days to 50 % flowering	≤ 43, NDYS-2, NDYS-38, NDYS-105
Days to maturity	≤ 103, NDYS-38, NDYS-102, NDYS-118
Plant height (cm)	≥ 110, NDYS-180, NDYS-229, NDYS-9509
Length of main raceme (cm)	≥ 50, NDYS-2, NDYS-130, NDYS-179
Number of primary branches/plant	≥ 10, NDYS-121, NDYS-174, NDYS-179,
Number of siliquae/plant	≥ 80, NDYS-132, NDYS-114, MYSL-201
Number of seeds/siliquae	≥ 25, NDYS-38, NDYS-44, NDYS-46
Length of siliquae (cm)	≥ 5.5, NDYS – 44, NDYS –101, NDYS –132
Test weight (g)	≥ 3.5, NDYS- 115, YSC-80, MYSL-207
Oil content (%)	≥ 43.5, NDYS-117, NDYS-118, NDYS -132
Seed yield/plant (g)	≥ 8.0, NDYS-136, NDYS-211, MYSL-201

Table 3. Direct and indirect effect of different characters on seed yield/plant at phenotypic and genotypic level of E_1

Character		Days to 50 % flowering	Days to maturity	Plant height (cm)	Length of main raceme (cm)	Primary branches/ plant	Number of siliquae/ plant	Number of seeds/ siliqua	Length of siliqua (cm)	Test weight (g)	Oil content (%)	Genotypic correlation with seed yield
Days to 50 % flowering	P	**0.080**	0.001	0.001	0.001	-0.006	-0.003	0.001	-0.002	-0.001	0.001	0.063
	G	**0.058**	0.004	0.076	-0.025	0.005	0.015	0.001	0.008	0.011	-0.019	0.134
Days to maturity	P	0.001	**0.103**	-0.003	-0.003	-0.005	-0.047	-0.001	-0.009	-0.003	0.001	0.034
	G	0.005	**0.038**	-0.128	0.288	0.001	-0.110	-0.002	0.004	-0.025	-0.004	0.067
Plant height (cm)	P	0.002	-0.009	**0.040**	0.047	0.082	0.254	0.002	0.022	0.010	-0.006	0.444
	G	0.002	-0.004	**0.672**	-0.391	-0.034	0.285	0.002	-0.018	0.049	-0.031	0.532
Length of main raceme (cm)	P	0.002	-0.003	0.024	**0.077**	0.042	0.121	0.001	0.015	0.009	0.002	0.290
	G	0.001	-0.006	1.000	**-0.732**	-0.024	0.224	-0.001	-0.013	0.051	0.030	0.530
Primary branches/plant	P	-0.005	-0.003	0.016	0.016	**0.207**	0.284	0.005	0.017	0.012	-0.008	0.541
	G	-0.005	-0.001	1.149	-0.694	**-0.059**	0.327	0.002	-0.015	0.031	-0.026	0.709
Number of siliquae/plant	p	-0.001	-0.009	0.018	0.017	0.106	**0.553**	0.002	0.020	0.001	0.003	0.710
	G	0.002	-0.009	1.228	-0.831	-0.042	**0.458**	0.001	-0.021	0.016	0.021	0.823
Number of seeds/siliqua	P	0.001	-0.001	0.002	0.001	0.020	0.024	**0.054**	0.019	-0.011	-0.020	0.089
	G	0.003	-0.003	0.185	0.044	-0.005	0.026	**0.025**	-0.017	-0.032	-0.122	0.104
Length of siliqua (cm)	P	-0.002	-0.010	0.009	0.012	0.037	0.113	0.012	**0.097**	0.001	0.002	0.271
	G	-0.009	-0.003	0.618	-0.369	-0.015	0.164	0.007	**-0.058**	0.003	0.023	0.361
Test weight (g)	P	-0.001	-0.004	0.005	0.008	0.031	0.001	-0.008	0.001	**0.078**	0.001	0.112
	G	0.005	-0.007	0.709	-0.644	-0.014	0.052	-0.006	-0.001	**0.136**	0.021	0.251
Oil content (%)	P	0.001	0.003	-0.003	0.002	-0.020	0.018	-0.013	0.002	0.001	**0.082**	0.073
	G	-0.003	0.001	-0.163	-0.136	0.004	0.026	-0.008	-0.004	0.008	**0.369**	0.094

Phenotypic residual effect = 0.4009, Genotypic residual effect = 0.4572, Bold value denote direct path effect

Table 4 Direct and indirect effect of different characters on seed yield/plant at phenotypic and genotypic level in E_2

Characters		Days to 50 % flowering	Days to maturity	Plant height (cm)	Length of main raceme (cm)	Primary branches/ plant	Number of siliquae/ plant	Number of seeds/ siliqua	Length of siliqua (cm)	Test weight (g)	Oil content (%)	Genotypic correlation with seed yield
Days to 50 % flowering	P	**-0.062**	0.001	0.001	0.001	0.001	0.048	0.014	0.001	-0.001	-0.001	-0.003
	G	**-0.041**	-0.007	0.005	-0.020	-0.008	0.130	0.066	-0.036	0.005	-0.016	0.078
Days to maturity	P	0.003	**0.005**	0.003	0.001	0.001	0.003	0.001	0.008	-0.001	0.003	0.027
	G	0.006	**0.051**	0.083	-0.042	-0.005	0.029	0.001	-0.060	0.001	0.009	0.073
Plant height (cm)	P	0.001	0.001	**0.029**	0.004	0.001	0.113	-0.006	0.014	0.003	-0.003	0.157
	G	-0.001	0.029	**0.146**	-0.253	0.007	0.262	-0.003	0.181	0.004	-0.020	0.352
Length of main raceme (cm)	P	0.001	0.001	0.009	**0.013**	0.001	0.088	0.002	0.010	0.003	-0.009	0.119
	G	-0.003	0.001	0.140	**-0.164**	0.006	0.185	-0.004	0.043	0.001	-0.023	0.182
Number of primary branches plant^{-1}	P	-0.008	0.001	-0.003	-0.002	**0.003**	0.032	0.002	0.009	0.009	0.006	0.048
	G	-0.011	0.008	-0.034	0.038	**-0.029**	0.072	0.003	0.037	0.004	0.009	0.097
Number of siliquae plant^{-1}	P	-0.005	0.001	0.008	0.004	0.002	**0.596**	0.010	0.008	0.001	0.004	0.629
	G	-0.001	0.001	0.055	-0.072	0.001	**0.654**	0.016	0.052	0.005	0.005	0.716
Number of seeds siliqua^{-1}	P	0.009	0.001	0.002	0.001	0.001	-0.052	**-0.098**	0.006	-0.007	0.012	-0.125
	G	0.018	-0.001	0.002	-0.007	0.001	-0.067	**-0.152**	0.050	-0.003	0.022	-0.137
Length of siliqua (cm)	P	0.001	0.001	0.004	0.001	0.001	0.039	0.194	**0.108**	0.003	-0.005	0.347
	G	0.005	-0.001	0.089	-0.038	-0.004	0.119	-0.027	**0.249**	0.033	-0.006	0.419
Test weight (g)	P	-0.002	0.001	0.001	0.001	0.001	0.100	0.011	0.006	**0.062**	-0.010	0.171
	G	-0.009	0.001	0.025	0.002	-0.005	0.141	0.024	0.025	**0.023**	-0.016	0.211
Oil content (%)	P	-0.001	0.001	0.001	0.002	0.001	-0.037	0.016	0.008	0.155	**-0.073**	0.073
	G	-0.008	-0.005	0.034	-0.067	0.003	-0.048	0.037	0.018	0.244	**-0.088**	0.120

Phenotypic residual factor =0.5754, Genotypic residual factor = 0.3452. Bold value denote direct path effect

Plant height, length of main raceme and number of primary branches/plant also had positive association with seed yield at E_1 but only plant height exerted high order direct effect on seed yield. The positive correlation of length of main raceme and number of primary branches/plant with seed yield was primarily due to its positive indirect effect via number of siliquae/plant (Patel et al., 1999). The direct effect of oil content on seed yield was positive (Patel et al., 1999). At E_2, length of siliqua and number of siliquae/plant had positive and significant association with seed yield. Evidently these characters have emerged as key components of seed yield. Besides, days to maturity, plant height and length of main raceme also manifested positive association with seed yield though their direct effect was not of high order. The direct effects of days to maturity and plant height were positive at both genotypic and phenotypic level at E_1 as well as at E_2. Plant height exerted its positive effect on seed yield mainly via number of siliquae/plant and length of siliqua. It may be inferred that plant height and number of siliquae/plant are the key component that determine and describe seed yield in the material under study.

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Phenotypic stability of yield and its component traits in toria, *Brassica campestris* (L.) var. toria

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Abstract

Thirty four genotypes of toria were evaluated under eight diverse environments for stability analysis for yield and its related traits. Pooled analysis of variance for all the thirteen characters indicated significant differences among the genotypes and environments. The linear component was observed to be significant for all the characters except number of primary branches suggesting that the prediction of performance of genotypes was possible across the environments. Genotype IC 212033 was observed to be desirable and stable for seed yield as well as other characters like days to maturity, plant height, number of primary and secondary branches/plant, siliqua length and biological yield. Further, the genotypes IC 259447 and IC 259462 were having high yield, $S^2di=0$ and b>1 indicating that these genotypes would perform better in favourable conditions.

Key words: Toria, stability, seed yield, regression coefficient

Introduction

The effects of genotype and environment on phenotype may not be always independent. The phenotypic response to change in environment is not same for all genotypes, the consequences of variation in phenotype depend upon the environment. Since GxE interaction has marking effect on genotype (Comstock and Moll, 1963) hence these interactions are of considerable importance to plant breeders in identifying the genotypes suitable for favourable location/environment and assumes importance for potential expression of characters under interest. The importance of GxE interactions is recognized well and these are known to be heritable and statistical techniques are available to estimate them. The main efforts of geneticists are to reduce them or to scale them out. The genotypes adjusting their phenotypic state in response to the environment so that they are able to give their maximum yield or near maximum economic returns are called "well buffered" genotype (Allard and Hansche, 1964). Hence present investigation was carried out utilizing 34 genotypes over diverse eight environments to assess to the stability of seed yield and its component traits in Toria.

Materials and methods

The present experiment was conducted during two years (2003 and 2004) at two diverse locations i.e., Simbhaoli, UP and R.S. Pura, J&K with early and late sowings. The 34 genotypes procured from NBPGR, New Delhi, were grown in Randomized Block Design with three replications under eight environments. Each entry was sown in single row of 3 m length with a distance of 30 cm and 15 cm between rows and plants, respectively. In each replication the observations were recorded on five randomly selected plants in each plot on seed yield and related traits. Plot means were subjected to stability analysis as per model given by Eberhart and Russell (1966).

Results and discussion

The pooled analysis of variance for GxE was highly significant for all the 13 characters, thus indicating the presence of genetic variability in the material studied and also the variation in the environment under study (Table1). The analysis of variance also exhibited that linear component of environment was significant for all the characters except number of primary branches. Variance due to GxE was highly significant for all the characters except plant height, number of secondary branches, 1000 seed weight and oil content indicating the differential response of genotypes in the expression of characters under varying environments. Similar to the present results Mahto (1996), Krishnanand and Bhajan (1997), and Dhillon *et al.* (2001) also reported that the environmental linear component was highly significant for all the characters. The linear portion of GxE was important for days to maturity, number of primary and secondary branches, number of siliqua/plant, number of seeds/siliqua, seed yield, biological yield, harvest index and 1000 seed weight reflecting the predictability of the performance of genotypes over environments while the non-linear portion of GxE interaction was important for days to 50% flowing, plant height and oil content and for siliqua length both linear and non-linear components were equally important (Table 1). Chaudhary *et al.* (2004) also reported that linear component was pre-dominant for days to flowering, days to maturity, siliqua on main shoot, number of siliqua/plant, seed yield, 1000-seed weight harvest index and oil content in Indian mustard.

Eberhart and Russell (1966) suggested that both linear sensitivity coefficient (bi) and non-linear sensitivity coefficient (S^2di) should be considered in assessing the phenotypic stability of a genotype and considered three *stability parameters viz.*, mean performance (x), regression coefficient (bi) and deviation from regression (S^2di). Based on stability parameters the genotypes IC 259352, IC 259353, IC 259355, IC 259445, IC 259446, IC 2594467, IC 259468 and IC 268317 were found to be stable and desirable for days to 50% flowering (Table 2). Mean number of days taken to maturity ranged from 91.5 (IC 259353) to 98.4 (IC 212077) over eight environments with a general mean of 94.3 days. The genotypes IC 259351, IC 259445, IC 259447, IC 259457 and IC 259460 with low mean, unit regression (b=1) and $s^2d=0$ were identified as desirable and stable for days to maturity (Table 2). For plant height , the genotype IC 259462 had high mean and b>1 indicating better response to favourable environment. Only 10 genotypes namely IC 212034, IC 212077, IC 212129, IC 230974, IC 259230, IC 259340, IC 268313, IC 268317, IC 268318 and IC 268326 had high mean, b=1 and $s^2d=0$ and were screened as desirable and stable across the environments for plant height. Genotype IC 259465 for number of primary branches; IC 212077, IC 212129, IC 259230 and IC 259353 for number of secondary branches; IC 259462 and IC 259353 for siliqua length showed high mean, average response (b=1) and non-significant s2di indicating predictable performance and found to be stable over environments.

The genotypes IC 212077 and IC 259340 for seeds/siliqua; IC 212033 and 259444 for seed yield; IC 259351 and IC 259443 for 1000 seed weight and IC 212032, IC 212077, IC 212129, IC 259353, IC 259355, IC 259443, IC 259444, IC 259445, IC 259462 and IC 259468 for oil content showed high mean performance, b=1 and $s^2di=0$ indicating stable performance over environments.

The genotypes IC 212032, IC 214824, IC 259230, IC 259340, IC 259443, IC 259445, IC 259446, IC 259449 IC 259467, IC 268318 and IC 268326 for seed yield; IC 212032, IC 259230, IC 259448 and IC 259456 for biological yield and IC 259355, IC 259446, IC 259461 and IC 268326 for harvest index showed below mean performance, unit regression coefficient and non-significant s^2di (Table 2). This indicated that the performance of these genotypes can be improved by adopting suitable management practices and can also be used as one of the parents along with high mean performance to breed genotypes with high mean performance and wider adaptation. Further the genotypes IC 259447 and IC 259462 were observed to be high yielding and stable but their corresponding bi values were significantly greater than unity. This showed that these genotypes would perform better in favourable conditions and hence could be recommended for cultivation in high fertility areas and management practices. Furthermore, genotypes IC 212034, IC 259444 and IC 268321 had mean seed yield greater than population mean and was stable ($s^2di=0$) but their bi values were significantly lower than unity (b<1). It indicated that these genotype would perform better in poor environmental conditions and hence these genotype can be used as a donor parent to breed a suitable genotype for poor environment (Table 2).

The results of the present study indicated that none of the genotype studied was found superior for all the characters in all the environments. The stable genotypes identified could be used as parents in future breeding programme for developing suitable genotypes with wider adaptability.

Table 1 Joint regression analysis for yield components in *toria*

Source of variance	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches	No. of secondary branches	No. of siliquae/ plant	Siliqua length (cm)	No. of seeds /siliquae	Seed yield /plant (g)	Biological yield (g)	Harvest index (%)	1000-seed weight (g)	Oil content (%)
Genotypic	33	12.80**	23.59**	777.83**	1.57**	3.27**	2293.78**	1.01**	16.47**	9.63**	308.51**	72.95**	2.38**	41.94**
Environment	7	6.09**	103.23**	174.51**	0.16	6.91**	9415.32**	2.66**	15.66**	37.71**	319.48**	111.56**	2.28**	4.26**
GxE	231	1.59**	4.02**	35.79	0.58**	1.88	861.99**	0.36**	4.21**	2.76**	86.09**	19.48**	0.15	0.69
E+GxE	258	1.72	6.94	39.87	0.57	2.02	1113.56	0.42	4.54	3.79	92.95	22.19	0.21	0.79
E (linear)	1	42.62**	722.13**	1223.33**	1.16	48.43**	65909.99**	16.63**	109.57**	263.99**	2236.44**	780.89**	15.96**	29.84**
GxE (linear)	33	1.44	4.21	25.71	0.84**	2.25	1158.94	0.35	4.60	4.46**	173.66**	47.33**	0.24**	0.46
Pooled deviation	204	1.56**	3.87**	36.36**	0.52**	1.76**	788.59**	0.35**	4.02**	2.41**	69.39**	14.40**	0.13**	0.70**
Pooled error	528	0.69	1.51	31.08	0.26	1.63	253.81	0.12	1.26	1.67	32.98	4.10	0.21	0.63

** Significant at P=0.01 level

Table 2 Estimates of stability parameters in 34 genotypes of *toria*

Genotypes	Days to 50% flowering			Days to maturity			Plant height (cm)			No. of primary branches			No. of secondary branches			No. of siliqua/plant		
	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d
IC-212032	23.33	2.30	0.63	94.33	1.27	1.15	68.29	1.09	-2.18	3.64	0.08	0.11	10.00	-0.11	1.20	181.59	0.95	348.37
IC-212033	25.62	1.54	1.22+	94.08	1.36	1.89	81.50	1.95	3.19	3.47	-4.40	0.11	9.45	2.26	0.51	163.12	1.41	1000.87++
IC-212034	27.00	-0.90	2.78++	97.83	0.81	2.02	96.85	2.55	24.56	3.15	-5.57	0.22	10.07	1.90	1.12	170.23	0.13	2335.40++
IC-212077	25.12	0.83	4.51++	98.38	0.95	1.80	90.61	1.11	-0.83	4.51	-0.02	0.48+	11.6	1.77	-0.01	197.52	0.57	642.34++
IC-212129	23.83	2.43	2.05++	93.42	1.99*	4.67++	89.65	1.50	27.94	4.27	4.93	0.09	12.11	0.81	2.27	198.93	0.77	604.26++
IC-214824	24.75	2.88	1.99++	92.92	1.27	1.58	72.62	1.96	-0.99	3.49	0.81	-0.06	9.78	-0.16	0.79	178.21	1.13	202.81
IC-230974	25.96	0.42	1.64+	95.75	1.58	10.06+*	110.31	1.48	54.40	3.94	-4.10	0.44	10.87	-0.05*	0.26	207.43	-0.03	1469.65++
IC-259230	25.08	-0.03	0.65	95.00	0.82	1.71	85.33	1.85	51.23	3.91	-8.15	1.27++	11.91	-1.23	1.87	190.48	0.60	127.62
IC-259340	24.58	1.68	1.06	96.62	0.45	5.73++	89.86	2.00	10.28	3.35	8.43	0.25	9.80	0.72	2.92+	188.35	0.59	1298.11++
IC-259351	23.71	1.48	1.03	92.68	1.04	2.44	77.27	1.24	2.21	3.38	0.27	1.07++	9.94	0.10	1.92	185.60	0.02	512.73+
IC-259352	23.46	2.25	0.45	93.71	1.44	0.71	79.09	1.63	68.08+	3.38	4.30**	-0.01	10.38	1.42	-0.10	188.84	1.84	397.83
IC-259353	21.58	1.26	0.17	91.53	0.35	3.89++	76.32	-0.07	70.81+	3.71	2.01	0.01	12.02	1.28	-0.16	164.94	0.39	28.86
IC-259355	22.79	1.40	0.25	93.50	1.05	1.76	68.86	1.02	13.97	3.48	-0.60	0.48+	10.90	2.68	2.45	175.58	2.01	679.11++
IC-259441	23.67	1.24	0.71	94.38	0.50	5.93++	70.99	2.26	67.30+	3.09	-0.81	0.39	9.61	2.31	0.93	157.44	1.68	519.46+
IC-259443	23.50	1.56	0.41	92.88	0.36**	1.14	72.54	-0.36	33.95	3.60	5.83	0.64++	10.24	1.40	4.44++	193.14	-0.29*	459.52+
IC-259444	23.88	0.51	-0.03	94.54	1.13	0.64	70.58	-0.26	74.13	3.56	7.11**	-0.07	10.07	1.83	2.38	191.99	0.01	842.32++
IC-259445	23.25	-0.11	0.65	92.79	0.99	0.84	73.53	-0.05	73.52	3.64	7.55*	0.08	9.66	1.18	0.18	171.97	1.80	743.37++
IC-259446	24.08	2.86	0.87	94.83	1.48	2.59	71.23	0.85	-1.21	2.99	4.88	0.26	8.78	0.22	1.21	170.69	1.37	459.44+
IC-259447	23.79	0.36	-0.04	91.92	1.20	1.16	74.73	1.44	20.11	4.28	-2.45	0.71++	10.71	0.57	2.18	184.40	0.29	690.45++
IC-259448	24.88	1.73	3.70++	95.67	0.62	4.75++	76.62	1.21	36.03	3.66	3.67	0.54+	10.44	1.48	2.15	186.28	2.22**	61.50
IC-259449	23.83	-0.83	0.81	92.50	1.26	2.70+	69.80	0.58	38.20	3.30	5.20	0.17	9.92	-157**	0.77	153.70	1.09	1035.06++
IC-259456	23.25	-0.96	2.20++	93.25	0.96	-0.30	71.01	1.32	14.11	4.34	-6.84	2.18++	12.46	-0.42	4.89++	181.04	1.96	680.69++
IC-259457	22.79	1.12	1.32+	92.54	1.18	1.28	62.26	0.79	2.01	4.07	3.36	0.65++	9.45	1.72	0.51	174.48	1.85	2233.66++
IC-259460	24.29	-0.07	0.67	92.33	0.87	-0.06	74.18	1.84	29.12	4.15	1.29	0.26	10.32	-0.23	0.18	186.35	1.59	843.85++
IC-259461	26.00	2.55	3.15++	97.54	1.22	4.40++*	81.67	1.39	7.91	3.49	8.65	0.30	10.11	0.42	0.20	214.66	0.15	1232.93+
IC-259462	27.33	1.16	4.19++	96.50	0.87	1.97+	82.17	-1.21*	29.89	4.55	4.46	1.25++	10.63	5.18	1.78	214.03	1.46	546.01+
IC-259465	24.21	0.26	0.38	93.88	0.57	1.67	71.38	0.91	-6.41	4.82	-3.16	0.16	11.33	0.58	1.50	202.9	1.24	671.60++
IC-259467	22.79	-0.48	0.46	92.96	0.88	5.35++	73.91	0.09	13.80	4.23	6.20	0.61+	9.95	1.16	0.54	192.80	2.26	559.36+
IC-259468	22.88	0.97	0.09	92.96	1.25	0.91	61.44	1.30	46.19	3.41	-0.04	0.26	9.48	2.14	0.79	143.07	1.04	957.90++
IC-268313	24.79	1.43	3.93++	94.38	2.05	12.93++	84.39	0.99	6.48	3.77	-2.84	0.35	10.19	1.02	-0.16	198.48	2.05**	192.03
IC-268317	22.79	0.37	0.18	95.54	0.09	17.65++	82.97	1.18	20.39	3.43	8.42	0.56+	10.86	-0.48*	0.01	207.97	0.70	609.10+
IC-268318	24.37	0.43	0.19	95.79	0.44*	1.24	83.20	-0.04	1.35	3.85	6.59	0.50+	10.12	1.44	1.60	198.23	0.49	102.19
IC-268321	24.71	0.16	0.19	94.71	0.64	3.10+	80.42	0.36	20.17	3.93	4.93	0.39	10.33	0.87	0.07	199.27	0.04	679.46++
IC-268326	25.75	2.21	3.03++	93.83	1.08	5.31++	84.65	0.02	34.32	4.01	-3.14	0.34	11.49	1.77	0.86	179.79	0.35	172.65
Mean	24.22			94.28			78.24	Q		3.76			10.46			185.07		
SEm±	0.47	1.11		0.74	0.42		2.27	1.00		0.27	3.93		0.50	1.11		10.61	0.63	

Table 2 Contd....

Genotypes	Siliqua length (cm)			No. of seeds/siliqua			Seed yield (g)			Biological yield (g)		
	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d
IC-212032	4.47	1.13	0.43++	14.29	2.32	2.35+	8.76	1.45	0.42	30.50	1.53	34.85
IC-212033	3.71	1.69	0.15	12.26	-0.33*	0.77	10.71	0.90	0.67	37.81	0.66	45.51
IC-212034	4.32	1.73	0.69++	14.46	0.34	3.29++	10.13	-0.55*	3.57	36.08	-2.71	81.81++
IC-212077	4.38	0.34	0.14	15.12	1.26	1.62	9.60	0.88	0.75	43.22	1.29	74.52+
IC-212129	3.82	1.95	0.49++	12.92	1.02	0.42	9.11	1.36	1.12	38.80	0.47	30.92
IC-214824	3.48	0.64	0.02	13.14	0.57**	0.65	8.41	0.43	0.37	35.02	-0.18	137.89++
IC-230974	4.31	1.33	0.71++	17.59	1.96	1.88	12.11	1.75	14.81++	54.40	-3.00	237.16++
IC-259230	3.61	1.22	0.80++	12.90	0.53	4.53++	8.48	0.70	0.28	36.72	1.22	17.70
IC-259340	3.84	0.67	0.31++	15.40	0.45	1.99	8.40	0.91	0.67	38.89	1.96	38.69
IC-259351	4.13	0.50	0.34++	15.43	0.99	6.67++	9.75	0.55	-0.09	43.69	1.37	79.77+
IC-259352	4.31	0.87	0.20+	15.15	-0.65	4.19++	8.63	0.12*	0.70	30.28	-0.93*	31.72
IC-259353	4.60	1.20	0.16	13.21	-0.46	4.27++	8.88	2.40**	0.90	34.01	2.26	117.60++
IC-259355	4.06	1.58	0.23+	15.54	2.15	4.19++	9.27	1.29	2.41	43.14	2.11	24.12
IC-259441	3.55	0.38	0.46++	12.51	-0.05	5.78++	8.81	2.04**	0.15	34.00	-0.09*	2.74
IC-259443	3.39	0.94	0.13	14.64	1.82	2.57+	8.44	1.19	-0.37	37.90	0.71	-1.89
IC-259444	3.28	0.16	0.07	13.26	-0.58	7.31++	10.84	0.87*	1.65	44.77	-0.71	87.48++
IC-259445	4.30	0.80	0.91++	16.30	0.98	2.33+	8.45	0.90	0.98	37.96	0.12	24.72
IC-259446	3.96	1.50	0.14	13.99	1.49	2.40+	8.36	0.86	0.48	39.98	2.00*	2.15
IC-259447	4.17	0.97	0.05	13.46	1.23	2.31+	11.42	2.56*	3.13	45.09	1.11	13.47
IC-259448	3.88	2.42	0.23+	13.91	2.07	2.24+	9.47	0.65*	0.70	37.07	0.14	44.67
IC-259449	4.14	1.89	0.53++	13.21	2.72**	-0.22	6.84	0.74	1.32	34.63	2.15	67.10+
IC-259456	3.84	1.09	0.17	13.12	3.18	4.95++	8.05	0.20	2.39	31.94	1.38	27.76
IC-259457	4.15	1.31	0.32++	14.14	2.87	10.28++	7.91	1.75*	0.39	34.54	3.32*	47.91
IC-259460	3.83	0.56	0.15	14.59	0.79	2.55+	9.40	0.63	0.10	39.97	1.09	52.90
IC-259461	4.11	1.63	0.19	11.83	1.40	4.34++	9.35	0.81	0.72	45.77	2.81**	-0.20
IC-259462	4.50	1.85	0.18	14.14	2.28	3.11++	10.81	2.35*	8.15	48.88	3.83**	52.11
IC-259465	3.58	2.03	0.54++	10.72	1.29	0.59	8.88	1.11	5.03++	42.46	3.03*	33.54
IC-259467	4.36	0.38	0.17	15.82	-0.48	2.86+	8.14	1.67	0.60	42.94	2.83	121.58++
IC-259468	4.49	1.62	0.36++	15.12	3.34**	2.36+	8.75	1.50	3.16+	38.03	1.13	40.81
IC-268313	3.53	-0.21*	0.09	15.43	-1.02	8.32++	9.33	0.18	2.50	48.53	-1.26	107.43++
IC-268317	4.23	-0.10	0.55++	16.34	-0.36	11.08++	9.87	0.96	0.05	54.08	1.27	73.94+
IC-268318	4.20	-1.61*	0.51++	13.23	1.03	3.41++	8.55	0.44	1.40	33.74	-1.57**	32.91
IC-268321	4.35	0.34	0.06	14.42	0.57	0.94	10.27	-0.86**	1.16	47.70	2.20	73.05+
IC-268326	4.08	1.03	0.10	13.09	0.43	6.25++	8.27	1.26	2.72	45.57	2.43	128.84++
Mean	4.02			14.13			9.18			40.24		
SEm±	0.22	0.80		0.75	1.11		0.58	0.55		3.14	1.02	

Table 2 Contd....

Genotypes	Harvest index (%)			1000-seed weight (g)			Oil content (%)		
	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d	$\bar{x}$	b	S^2d
IC-212032	29.23	0.09	10.00+	3.37	1.73	-0.04	39.24	0.68	0.06
IC-212033	29.13	1.88	32.15++	2.86	0.90	0.05	37.54	1.06	0.03
IC-212034	29.52	0.03	26.71++	2.09	0.90	0.03	35.37	0.13	0.06
IC-212077	22.72	1.12	7.23+	3.47	0.89	0.01	40.02	0.80	0.04
IC-212129	23.33	0.80	0.54	3.14	0.87	0.03	39.53	-0.27	0.38
IC-214824	25.46	-2.27**	9.98+	2.34	0.42	-0.03	35.83	0.39	0.30
IC-230974	22.36	1.78	6.69	2.89	0.49	0.03	38.15	0.41**	-0.18
IC-259230	23.40	1.43	3.98	3.16	0.55	0.18	35.48	-0.52	0.66
IC-259340	22.21	1.81	12.52++	3.68	-0.09	0.18	35.72	0.91	-0.06
IC-259351	23.24	-1.44**	14.71++	4.27	1.27	0.00	38.22	1.32	0.22
IC-259352	29.83	2.80	36.71++	3.59	0.47	-0.01	36.42	0.64	0.05
IC-259353	27.05	-2.37**	8.70+	3.70	-0.22	0.17	38.82	0.19	-0.06
IC-259355	21.49	1.01	0.45	3.70	1.26	0.06	39.19	1.11	-0.18
IC-259441	26.02	1.46	33.60++	3.33	0.26	0.05	38.24	0.69	0.14
IC-259443	22.33	1.68*	0.85	4.29	0.21	-0.05	42.00	1.36	-0.16
IC-259444	24.87	2.18	14.08++	3.30	0.71	0.18	42.29	-0.58	0.56
IC-259445	22.33	0.44	7.59++	3.94	2.45**	0.04	41.37	1.49	0.07
IC-259446	21.12	0.27	6.02	3.50	1.68	-0.01	40.57	2.00*	-0.08
IC-259447	25.36	2.80*	11.54++	3.71	1.04	0.00	36.92	1.39	0.18
IC-259448	26.39	2.28	22.12++	4.28	2.32	0.54++	36.59	1.55	0.25
IC-259449	20.43	0.09	8.59+	3.96	2.52**	0.05	37.15	0.48	0.22
IC-259456	25.78	0.62	19.31++	3.29	1.58	0.04	35.85	1.33	-0.14
IC-259457	24.04	-0.14	14.70++	3.73	1.53	0.01	35.61	1.99**	-0.13
IC-259460	24.71	2.09	13.80++	3.32	1.63	-0.02	35.28	1.16	0.20
IC-259461	20.72	0.28	5.73	3.65	2.02**	-0.02	40.45	0.85	4.73++
IC-259462	21.97	0.53	8.04+	3.58	0.33	0.06	42.33	0.86	0.06
IC-259465	21.08	-1.57**	10.27++	3.16	1.89	0.39+	37.47	1.44	3.09++
IC-259467	20.10	3.00**	1.28	3.18	0.77	0.12	39.50	2.96	3.20++
IC-259468	23.25	0.86	14.10++	3.49	0.51	0.00	41.40	1.61	0.00
IC-268313	20.29	3.03**	3.86	2.88	0.56	0.00	38.65	1.63	3.46++
IC-268317	19.02	2.25**	1.38	3.11	1.05	0.03	36.64	1.48	-0.07
IC-268318	26.52	3.03	24.93++	2.15	0.71	-0.01	34.57	1.19	0.10
IC-268321	22.65	0.70	49.18++	2.73	-0.06	0.12	36.99	1.35	0.01
IC-268326	18.50	1.45	1.88	3.94	0.83	0.00	34.96	0.90	-0.08
Mean	23.71			3.77			38.06		
SEm±	1.43	0.79		0.13	0.54		0.31	0.89	

*,** Significantly deviating from unity at P=0.05 and P=0.01 levels, respectively;
+,++ Significantly deviating from zero at P=0.05 and P=0.01 levels, respectively

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Genetic analysis for leaf area index in sunflower, *Helianthus annuus* L.

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Abstract

A diallel set of 28 F_1's involving eight inbred lines excluding reciprocals along with eight parents was raised over four environments to estimate gene effects, combining ability and its interaction with environment for leaf area index in Spring 2003. Analysis of variance over environments indicated that parents and hybrids differed significantly. Significant parents vs hybrids x environment interaction indicated that heterotic effects vary with change in environment. The parents and hybrids differed significantly with respect to their *gca* and *sca* respectively. The significant females x males x environment interaction indicated that combining ability of the lines vary with change in environment. The non additive gene effects were found to be predominant and these were more prone to environmental fluctuations than additive effects. The Leaf area index was found to be positively correlated with seed yield. The parents 1136-1 and Acc. No. 220 were identified as good general combiners for leaf area index.

Key words: Leaf area index, combining ability, *gca, sca,* heterosis

Introduction

Oil yield in sunflower is reduced when normal spring sowing was delayed in both temperate and subtropical environments (Patil *et al.*, 1989). The lower yields associated with late plantings have been hypothesized as due to warm temperatures during the early growth period which promotes excessive stem growth (Beard and Geng, 1982) and reduced time to flowering. Leaf area is of value as an index of plant growth and in addition is related to the accumulation of drymatter, plant metabolism and yield. Crop quality and maturity may also be related to leaf area. The ratio of leaf surface area to unit ground cover called leaf area index is an integrative measure of carbon and water balance in plants and is one of the major components of plant productivity (Cowling, 2003). Accurate estimate of leaf area index is needed because of the importance of canopy structure in gas, water, carbon and energy exchange. Many of the studies have not specifically examined the physiological basis of yield response to late sowing or attempted to relate these to a selection strategy. Developing an understanding of the biophysical basis for these interactions could lead to identification of opportunities for genetic improvement to overcome this constraint to production (Basford and Cooper, 1998). Further, for the improvement of a trait through heterosis breeding it is imperative to study the magnitude of heterosis available and combining ability of the lines. There is no report available in the literature on these aspects in respect of leaf area index in sunflower. Keeping these points in view the experiment was planned to study the effect of leaf area on seed yield and to estimate heterosis and combining ability effects for leaf area index in different environments.

Materials and methods

A set of 28 crosses was synthesized by crossing in a diallel fashion excluding reciprocals, eight inbred lines *viz.*, IL-GP_6-28, IL-EC-43, IL-SF-78, IL-IP-226, IL-OH-130, IL-M-194, 1136-1 and Acc. No.220. The crosses were made by spraying GA3 (100 ppm) at star bud stage for three consecutive days in the evening to induce male sterility in the female parents. The material was grown in a Randomized Complete Block Design with three replications over four environments. The environments were created by sowing the experiment on 2 dates at two locations (Ludhiana January 23, and February, 25 and Faridkot February 7 and 26). The combining ability analysis over environments was done following Singh (1979). The simple correlations were worked out following the procedure given by Dewey and Lu (1959). Leaf area index was recorded on five random plants.

Results and discussion

The mean squares due to genotypes were highly significant for leaf area index for individual environments as well as over all the environments. Highly significant GxE interactions showed differential behavior of genotypes over all the environments (Table 1). A genotype x sowing date interaction for yield (Beard and Geng, 1982; Miller *et al.*, 1984) has also suggested the existence of genetic variability for traits related to specific adaptations to late plantings. Genotypic variation in maximum leaf area and in leaf area index has also been observed by Gimeneg and Fereres (1986). In the present study parents and hybrids behaved differently in the diverse environments as revealed by the significant variances due to environments, parents and hybrids x environments interactions. There

was positive correlation between leaf area index and days to maturity ® =+ 0.017), however, leaf area index showed significant positive correlation with plant height ® =+0.4) and seed yield ® =+0.6).The parent Acc. No. 220 which matured in 99 days, had more leaf area index (2.30) and more seed yield/plant (20.2g) as compared to parent IL-GP6-28 with LAI of 1.23 which matured in 93 days and had 16.7 g seed yield/plant. The parent IL-SF-78 had leaf area index of 1.11 but its seed yield/plant was maximum (22.8g) which indicates that plant type of this parent is ideal in using sunlight for photosynthesis and further translocation to the sink (Table 4). The significance of (P vs H)x E interaction indicated the influence of environment on the manifestation of heterosis. The magnitude of heterosis had a wide range from -30.43 to 163.21%. The cross combination IL-EC-43 x IL-IP-226 manifested the highest heterosis (163.2) followed by IL-GP_6 -28 x IL-IP-226 (148.8), IL-OH-130 x IL-M-194 (147.9). A total of 23 cross combinations exhibited significant positive heterosis.

Combining ability analysis: Mean squares due to *gca* and *sca* were highly significant under each environment. In the pooled analysis the parents and the hybrids differed significantly with respect to their *gca* and *sca* effects respectively (Table 1). The gca as well as *sca* variances showed significant interactions with the environment. La Vega and Hall (2002) reported that GxE interaction accounted for a portion of the total variability three times higher than the contribution of genotypes alone. They also observed biomass differences between planting dates to be dominant determinant of the sowing date effect on yield. Also a predominant role of the non-additive gene effects in the expression of leaf area index was observed. In the present study also parents interacted differently in different environments with respect to leaf area index as well as seed yield/plant (Table 4). Maximum leaf area index was observed in February sown crop at Faridkot (E_3) and it was positively correlated with seed yield also since highest seed yield/plant was recorded in this environment. Minimum leaf area index and seed yield/plant were observed at Ludhiana in January sown crop (E_1). A similar trend was observed for crosses (Table 4). The crosses (IL-SF-78 x IL-IP-226) and (IL-OH-130 x Acc. No. 220) had less leaf area index but gave more seed yield/plant at Faridkot as compared to Ludhiana.

Table 1 Analysis of variance

Source	Over environments		Combining ability over environments		
	df	MS	Source	df	MS
Environ (E)	3	46.13**	*gca*	7	0.85**
Parents (P)	7	1.95**	*sca*	28	23.56**
Hybrids (H)	27	2.32**	Env (E)	3	46.13**
P vs H	1	65.11**	*gca* x E	21	0.04**
P X E	21	0.03**	*sca* x E	84	1.66**
H X E	81	0.18**	Error	280	0.01
(P vs H) X E	3	12.78**			0.01
Error	140				

** = Significant at 1% level.

Table 2 Estimates of general combining ability effects for individual environments and pooled over environment

Parent	E_1	E_2	E_3	E_4	Pooled
IL-GP6-28	0.04* (H)	0.07**(H)	0.13**(H)	0.17**(H)	0.10
IL-EC-43	-0.12**(L)	-0.13**(L)	-0.31**(L)	-0.29**(L)	-0.21**(L)
IL-SF-78	-0.06**(L)	-0.07**(L)	-0.16**(L)	-0.17**(L)	0.11
IL-IP-206	-0.02	-0.04**(L)	-0.01	-0.04**(L)	0.03
IL-OH-130	-0.10**(L)	-0.10**(L)	-0.18**(L)	-0.18**(L)	-0.14*(L)
IL-M-194	0.03*(H)	0.02	0.09**(H)	0.07**(H)	0.05
1136-1	0.09**(H)	0.09**(H)	0.22**(H)	0.24**(H)	0.16*(H)
Acc.No.220	0.14**(H)	0.16**(H)	0.21**(H)	0.19**(H)	0.18**(H)
SE (gi) +	0.01	0.01		0.01	0.05

L = Low; H = High

Table 3 Best crosses based on *per se* performance, heterosis and *sca effects pooled* over environments

Per se performance	*sca* effects	Heterotic effects (%)
IL-SF-78 x ACC.NO.220(3.4)	IL-SF-78 x ACC.NO.220(1.2)	IL-GP_6-28 x IL-IP-226(148.8)
IL-GP_6-28 x 1136-1 (3.4)	IL-GP_6-28 x 1136-1 (1.0)	IL-GP_6-28 x 1136-1 (134.5)
IL-GP_6-28 x IL-IP-226 (3.1)	IL-OH-130 x IL-M-194 (1.0)	IL-EC-43 x IL-IP-226 (163.2)
IL-OH-130 x IL-M-194 (3.1)	IL-GP_6-28 x IL-OH-226 (09)	IL-SF-78 x IL-OH-130 (134.2)
IL-GP_6-28 x IL-M-194 (2.9)	IL-SF-78 x IL-OH-130 (0.7)	IL-OH-130 x IL-M-194 (148.0)

Table 4 Mean performance of parents and hybrids for LAI and seed yield in different environments

Parents/ Hybrids	E_1		E_2		E_3		E_4		Pooled	
	LAI	S Y	LAI	S Y	LAI	S Y	LAI	S Y	LAI	S Y
IL-GP_6-28(P1)	1.00	21.00	0.89	8.20	1.60	23.50	1.40	13.80	1.23	16.73
IL-EC-43(P2)	0.89	9.40	0.70	3.80	1.40	18.50	1.20	17.30	1.06	12.29
IL-SF-78 (P3)	0.90	12.20	0.80	11.70	1.50	37.50	1.20	29.60	1.11	22.77
IL-IP-226 (P4)	0.70	9.00	0.60	9.50	1.20	33.30	1.50	18.60	0.92	17.68
IL-OH-130 (P5)	0.50	10.00	0.40	6.20	0.80	34.30	0.60	16.80	0.62	17.07
IL-M-194 (P6)	0.90	18.50	0.89	9.90	1.60	29.50	1.40	19.10	1.23	19.25
1136-1(P7)	1.16	16.50	1.00	7.70	1.90	21.80	1.70	20.30	1.45	16.58
Acc. No..220 (P8)	1.80	16.50	1.70	10.00	2.90	28.40	2.70	26.00	2.30	20.23
P1 x P2	1.00	19.60	0.94	14.10	2.92	51.30	2.73	22.20	1.90	26.81
P1 x P3	0.97	18.70	0.90	21.20	2.80	28.60	2.62	45.10	1.82	28.41
P1 x P4	1.61	28.70	1.51	17.00	4.70	26.10	4.45	46.30	3.06	29.52
P1 x P5	1.23	30.00	1.19	16.10	3.58	63.70	3.42	32.10	2.36	35.50
P1 x P6	1.47	20.00	1.41	23.10	4.29	39.60	4.22	60.20	2.85	35.66
P1 x P7	1.75	28.30	1.70	23.60	5.10	44.80	5.03	34.50	3.40	32.82
P1 x P8	1.23	22.00	1.21	23.20	3.58	30.00	3.44	51.50	2.37	31.68
P2 x P3	0.60	5.20	0.50	11.60	1.74	34.00	1.63	39.10	1.21	22.48
P2 x P4	1.47	3.80	1.35	23.10	4.26	41.20	4.09	37.20	2.79	33.08
P2 x P5	0.87	16.70	0.72	23.30	2.51	34.80	2.30	31.80	1.60	26.66
P2 x P6	1.21	20.30	1.14	27.50	3.54	23.00	3.30	36.30	2.30	26.76
P2 x P7	1.36	25.10	1.22	21.00	3.95	38.50	3.78	32.60	2.58	29.28
P2 x P8	1.37	29.60	1.33	21.90	3.98	39.20	3.80	52.10	2.63	35.71
P3 x P4	1.21	19.10	1.10	34.40	3.53	69.30	3.22	44.10	2.27	41.69
P3 x P5	1.37	24.70	1.22	20.70	3.99	47.70	3.80	51.80	2.60	36.22
P3 x P6	1.32	17.60	1.12	27.10	3.85	58.40	3.60	49.80	2.48	38.16
P3 x P7	1.11	29.50	1.05	35.30	3.21	56.90	3.04	44.60	2.11	41.58
P3 x P8	1.80	31.60	1.70	37.40	5.22	61.30	5.00	60.20	3.43	47.61
P4 x P5	1.13	14.60	1.10	13.70	3.30	23.90	3.07	28.80	2.15	20.31
P4 x P6	1.42	14.70	1.30	12.30	4.15	28.00	3.87	30.20	2.69	21.30
P4 x P7	1.33	18.60	1.26	17.90	3.86	26.30	3.57	30.60	2.51	23.07
P4 x P8	1.88	15.50	0.73	15.70	2.56	21.10	2.31	26.30	1.62	19.64
P5 x P6	1.60	32.40	1.52	16.70	4.65	34.10	4.44	32.90	3.05	29.01
P5 x P7	1.41	21.50	1.32	17.80	4.08	18.60	3.88	23.50	2.67	20.33
P5 x P8	1.12	24.20	1.02	9.20	3.27	27.30	3.03	29.50	2.11	22.52
P6 x P7	1.14	23.20	1.03	30.70	3.34	54.80	3.10	78.00	2.15	46.68
P6 x P8	0.94	24.70	0.83	19.50	2.72	43.30	2.43	45.80	1.72	33.11
P7 x P8	1.30	22.00	1.22	11.70	3.76	30.20	3.54	36.70	2.45	25.15

E_1 : PAU, Ludhiana (Jan. 23); E_3 : RRS., Faridkot (Fen. 07)
E_2 : PAU, Ludhiana (Feb. 25); E_4 : RRS, Faridkot (Feb. 26)

The mean squares due to *gca* x E and *sca* x E indicated that non-additive genetic variances were more prone to fluctuations due to interplay of genetic and environment factors. The mean square due to *sca* having higher magnitude than *sca* x E revealed that non-additive effects for leaf area index were relatively stable over varying environments. Similarly variance due to *gca* being greater in magnitude than *gca* x E, suggested that the additive effects fluctuated relatively less with the environmental changes as compared to *sca* effects.

The parents IL-GP_6-28, 1136-1 and Acc. No 220 displayed significantly positive while the parents IL-EC-43, IL-SF-78 and IL-OH-130 displayed significantly negative gca effects in all the individual environments (Table 2).The parents 1136-1 and Acc. No.220 were identified as good general combiners. The parent IL-GP_6-28, however, was not a good combiner for leaf area index in the individual environments but over the environments the *gca* effects were significant which reveals the greater role of the environment in establishing the combining ability in respect of leaf area index.

Seventeen cross combinations exhibited positive *sca* effects under all the individual environments. On the basis of pooled analysis a total of 16 hybrids possessed significant positive *sca* effects and the top most five cross combinations are IL-SF-78 x Acc. No. 220, IL-GP_6-78 x IL-OH-130, IL-GP_6-28 x 1136-1, IL-OH-130 x IL-M-194 and IL-GP_6-28 x IL-OH-226. (Table 3)

It is concluded that parents and hybrids interacted differently in different environments with respect to leaf area index and seed yield. The leaf area index was found to be positively associated with seed yield. Maximum leaf area index and seed yield per plant were observed at Faridkot location in early sown crop which reveals the role of environment in getting the potential yields from sunflower. The parents 1136-1 and Acc. No. 220 were identified as good general combiners for leaf area index.

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Influence of provenance, season and staggered planting on seed quality of sunflower, *Helianthus annuus* L.

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Abstract

A field experiment was carried out to study the effect of location, season and staggered sowing on seed quality attributes of sunflower cv. RSFH-1 during *kharif* and *rabi* season of 2003-04 at two locations i.e., Dharwad and Bagalkot. Significantly higher seed germination (88.3%), vigour index (2883), germination rate index (22.0) and oil content (35.3%) were recorded at Bagalkot location than Dharwad (83.6%, 2453, 19.5 and 31.3%, *respectively*). Similarly, all these quality parameters were significantly better during *rabi* than *kharif* season. The staggered sowing of male parent seven days early recorded optimum values for seed germination (84.2%), seedling vigour index (2426), germination rate index (20.2) and field emergence (76.8), which were in acceptable limits. Hence, Bagalkot and *rabi* season is better to produce good quality seed with the sowing of male parent seed seven days earlier than female parent.

Key words: *Provenance, season, seed quality,* staggered sowing, sunflower

Introduction

Good quality seed is the basis for successful seed production programme which in turn will ensure uniform germination and rapid root and shoot development and thus increase yield per unit area. Increase in use of high quality seed is one of the preventive steps against catastrophic food problem. Realization of higher seed yield *should always be accompanied by the production of* superior quality seed. The location, season and staggered sowing in seed production play great role in determining the seed quality, since seed development and maturity is largely influenced by these factors (Vanangamudi and *Karivartharaju, 1985*; Somasekhara, 1997). The present study was, therefore conducted to determine the influence of location, season and staggered sowing of quality on seeds of sunflower.

Materials and methods

A field experiment was conducted during *kharif* and *rabi* 2003-04 at Water and Land use Management Institute (WALMI), Dharwad and Agricultural Research Station (ARS), Bagalkot. The experiment was laid out in *Randomised Block Design* in with factorial concept with three replications. The seeds of parental lines (CMS103A and R-64NB) were treated with captan @ 2 g/kg of seeds. Female and male parents were sown on 1st August and 5th November 2003 as per the treatment (Table 1) during *kharif* and *rabi* season respectively at Dharwad, similarly on 13th August and 18th November at Bagalkot. Each plot was 5.4 m wide and 4.2 m length. A spacing of 60 cm between rows and 30 cm between plants with 3:1 female to male planting ratio was maintained. Soil types were black clay loam and deep black at Dharwad and ARS, Bagalkot, respectively. All the recommended seed production practices were carried out. After the harvest the seeds were dried, cleaned and processed for laboratory test of seed germination, seedling vigour index, germination rate index, oil content and field emergence by adopting the standard procedures.

Results and discussion

Significant differences were noticed due to provenance for seed quality parameters. Germination and seed vigour index were higher in the seeds produced at Bagalkot compared to Dharwad (Table 1). It is attributed due to the favourable environmental conditions like dry and cool weather and absence of rains prevailing during seed development stage. The results are in conformity with the findings of Vanangamadi and Karivaratharaju (1985).

Higher germination rate index and field emergence were recorded in the seeds produced at Bagalkot compared to Dharwad. This difference in seed quality parameters over the locations could be mainly due to better stored food reserves and healthy condition of seeds (Narayanswamy and Shambulingappa, 1994). The seeds produced at Bagalkot recorded higher oil content compared to Dharwad (Table 2). This difference may be due to the abiotic factors such as soil, rainfall and other environmental parameters (Yousuf Ali Khan *et al.*, 1973).

The germination per cent was found to be higher in the seeds produced during *rabi* season than *kharif* (84.8) (Table 1). This variation in germination between the season could be attributed to the better development of seeds during rabi season, which may be due to higher test weight seeds obtained in rabi than *kharif* season (Jagadish and Shambulingappa, 1983). Higher seedling vigour index and germination rate index in the *rabi*

compared to *kharif* was mainly due to the heavy seeds with better food reserves (Table 1). The seeds produced during *rabi* season recorded significantly higher field emergence compared to *kharif*. The oil content was more in rabi season compared to *kharif* (Table 2). This could be attributed to the bright sunshine hours and prolonged day length during flowering and seed development stage in *rabi* season (Habeebullah *et al.*, 1983).

The superiority in the seed quality parameters like seed germination, seedling vigour index, germination rate index and filed emergence in the seeds of simultaneous sowing of parental lines may be attributed to better translocation of photosynthates to the limited sink leading to better development of seeds compared to moderate values recorded with seven days staggering, which were also in acceptable limits (Somasekhara, 1997). Therefore, the present study amply shows that taking of seed production at Bagalkot during *rabi* season with staggering of male parent seven day early is found to be optimum to get better quality seeds compared to Dharwad location.

Table 1. Germination percentage, seedling vigour index and germination rate index as influenced by provenance, planting season and staggered sowing in sunflower

Treatment	Germination (%)							
	Location (L)		Season (P)		*Kharif* (P_1)		*Rabi* (P_2)	
	L_1	L_2	P_1	P_2	L_1	L_2	L_1	L_2
S_0	86.5 (68.4)	91.1 (72.7)	87.7 (69.4)	90.2 (71.8)	84.9 (67.1)	90.0 (71.6)	88.0 (69.8)	92.2 (73.7)
S_1	84.2 (66.6)	89.1 (70.7)	85.9 (68.0)	87.5 (69.3)	82.8 (65.5)	88.9 (70.5)	85.6 (67.7)	89.4 (71.0)
S_2	82.0 (64.9)	86.6 (68.3)	83.2 (65.8)	85.3 (67.4)	80.8 (64.0)	85.4 (67.5)	83.1 (65.7)	87.4 (69.2)
S_3	83.7 (66.2)	86.9 (68.7)	84.2 (66.6)	86.4 (68.3)	82.6 (65.3)	85.8 (67.9)	84.9 (67.1)	87.9 (69.6)
S_4	84.4 (66.7)	88.8 (70.4)	85.2 (67.4)	88.0 (69.7)	83.2 (65.8)	87.2 (69.0)	85.6 (67.7)	90.3 (71.8)
S_5	82.1 (64.9)	88.3 (70.0)	84.3 (66.6)	86.4 (68.4)	81.0 (64.1)	87.2 (69.0)	83.2 (65.8)	89.4 (71.0)
S_6	81.5 (64.5)	87.0 (68.9)	83.2 (65.8)	85.5 (67.6)	79.2 (62.8)	86.9 (68.7)	83.8 (66.2)	87.2 (69.0)
S_7	84.1 (66.5)	88.2 (69.9)	84.5 (66.8)	87.9 (69.6)	82.2 (65.0)	86.8 (68.7)	86.0 (68.0)	89.7 (71.2)
Mean	83.6 (66.1)	88.3 (70.0)	84.8 (67.0)	87.2 (69.0)	82.1 (64.9)	87.3 (69.1)	85.0 (67.2)	89.2 (70.8)
	L	L´S	P	P´S	L´P		L´P´S	
S.Em±	0.36	1.03	0.36	1.03	0.51		1.45	
CD (P= 0.05)	1.03	NS	1.03	NS	NS		NS	
	Seedling vigour index							
S_0	2748	3287	2931	3105	2615	3247	2882	3327
S_1	2483	2994	2665	2813	2373	2957	2594	3031
S_2	2260	2592	2325	2527	2126	2525	2395	2659
S_3	2408	2677	2464	2621	2357	2571	2460	2782
S_4	2642	2976	2665	2953	2528	2802	2755	3151
S_5	2346	2907	2524	2728	2267	2782	2425	3032
S_6	2271	2723	2442	2552	2116	2768	2426	2678
S_7	2467	2905	2559	2813	2344	2775	2590	3035
Mean	2453	2883	2572	2764	2341	2803	2566	2962
	L	L´S	P	P´S	L´P		L´P´S	
S.Em±	18.82	53.23	18.82	53.23	26.62		75.29	
CD at 5%	53.17	NS	53.17	NS	NS		NS	
	Germination rate index							
S_0	20.1	22.5	20.9	21.7	19.8	22.0	20.4	22.9
S_1	19.6	22.4	20.7	21.2	19.5	21.9	19.6	22.8
S_2	19.1	21.2	20.0	20.4	19.0	21.0	19.2	21.5
S_3	19.4	21.5	20.3	20.6	19.4	21.2	19.3	21.8
S_4	19.9	22.4	20.8	21.5	19.7	21.8	20.1	22.9
S_5	19.2	22.1	20.5	20.9	19.2	21.7	19.3	22.5
S_6	19.1	21.7	20.4	20.5	19.0	21.7	19.3	21.7
S_7	19.5	22.1	20.6	21.1	19.5	21.6	19.6	22.6
Mean	19.5	22.0	20.5	21.0	19.4	21.6	19.6	22.3
	L	L´S	P	P´S	L´P		L´P´S	
S.Em±	0.13	0.37	0.13	0.37	0.18		0.53	
CD (P= 0.05)	0.38	NS	0.38	NS	NS		NS	

NS : Non significant; * Figures in parenthesis indicates the arcsine values

L_1- Dharwad L_2- Bagalkot P_1- *Kharif* P_2- *Rabi*
S_0- Simultaneous sowing of female and male parent
S_1- Sowing of male parent four days early to the female parent
S_2- Sowing of male parent seven days early to the female parent
S_3- Sowing of male parent ten days early to the female parent
S_4- S_0 + spraying of urea (2%) at button formation stage to male parent
S_5- S_1 + spraying of urea (2%) at button formation stage to male parent
S_6- S_2 + spraying of urea (2%) at button formation stage to male parent
S_7- S_3 + spraying of urea (2%) at button formation stage to male parent

Table 2. Field emergence and oil content as influenced by provenance, planting seasons and staggered sowing in sunflower

Treatment	Field emergence (%)							
	Location (L)		Season (P)		*Kharif* (P_1)		*Rabi* (P_2)	
	L_1	L_2	P_1	P_2	L_1	L_2	L_1	L_2
S_0	79.5 (63.0)	84.2 (66.5)	80.5 (63.8)	83.2 (65.8)	77.8 (61.8)	83.2 (65.8)	81.1 (64.3)	85.1 (67.3)
S_1	77.1 (61.4)	82.0 (64.9)	78.7 (62.5)	80.4 (63.7)	75.6 (60.4)	81.8 (64.7)	78.5 (62.4)	82.3 (65.1)
S_2	74.7 (59.8)	78.9 (62.6)	75.9 (60.6)	77.7 (61.8)	73.1 (58.7)	78.6 (62.5)	76.3 (60.8)	79.2 (62.8)
S_3	75.5 (60.3)	79.3 (62.9)	77.6 (61.7)	77.3 (61.5)	75.3 (60.2)	79.8 (63.2)	75.7 (60.4)	78.8 (62.6)
S_4	77.5 (61.7)	82.2 (65.0)	78.9 (62.6)	80.9 (64.1)	76.6 (61.0)	81.2 (64.3)	78.5 (62.4)	83.2 (65.8)
S_5	77.6 (60.4)	81.4 (64.4)	77.8 (61.8)	79.4 (63.0)	74.3 (59.5)	81.0 (64.2)	76.9 (61.3)	81.8 (64.7)
S_6	75.6 (60.0)	80.1 (63.5)	76.7 (61.1)	78.5 (62.3)	73.2 (58. 8)	80.1 (63.5)	76.8 (61.2)	80.1 (63.5)
S_7	75.0 (63.2)	81.1 (64.2)	79.8 (63.3)	81.1 (64.2)	79.8 (63.2)	79.9 (63.3)	79.8 (63.2)	82.4 (65.2)
Mean	76.9 (61.2)	81.2 (64.3)	78.4 (62.3)	79.9 (63.3)	75.7 (60.5)	80.7 (63.9)	78.0 (62.0)	81.6 (64.6)
	L	L'S	P	P'S	L'P		L'P'S	
S.Em±	0.17	0.48	0.17	0.48	0.24		0.68	
CD (P= 0.05)	0.48	NS	0.48	NS	NS		NS	
	Oil content (%)							
S_0	32.15	35.48	33.15	34.48	31.43	34.87	32.87	36.08
S_1	30.94	35.05	31.87	34.11	29.73	34.01	32.14	36.08
S_2	30.99	35.43	32.17	34.25	29.60	34.74	32.37	36.12
S_3	31.07	35.87	32.44	34.50	29.91	34.96	32.23	36.77
S_4	31.44	35.71	32.61	34.54	30.25	34.96	32.62	36.47
S_5	31.09	34.82	31.97	33.95	29.50	34.43	32.68	35.21
S_6	31.71	35.45	32.27	34.89	30.33	34.21	33.09	36.69
S_7	31.27	35.05	31.72	34.60	29.89	33.55	32.65	36.55
Mean	31.33	35.36	32.27	34.41	30.08	34.47	32.58	36.25
	L	L'S	P	P'S	L'P		L'P'S	
S.Em±	0.17	0.48	0.17	0.48	0.24		0.68	
CD (P= 0.05)	0.48	NS	0.48	NS	NS		NS	

NS : Non-significant; * Figures in parenthesis indicates the arcsine values

L_1- Dharwad L_2- Bagalkot P_1- *Kharif* P_2- *Rabi*
S_0- Simultaneous sowing of female and male parent
S_1- Sowing of male parent four days early to the female parent
S_2- Sowing of male parent seven days early to the female parent
S_3- Sowing of male parent ten days early to the female parent
S_4- S_0 + spraying of urea (2%) at button formation stage to male parent
S_5- S_1 + spraying of urea (2%) at button formation stage to male parent
S_6- S_2 + spraying of urea (2%) at button formation stage to male parent
S_7- S_3 + spraying of urea (2%) at button formation stage to male parent

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Genetic analysis of induced variability for yield and yield attributes in sesame, *Sesamum indicum* L.

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Abstract

The sesame variety DS-1 was treated with three doses of gamma rays (300, 400 and 500 Gy) and EMS 0.50%. Analysis of variance of M_3 generation indicated highly significant differences among parents. The yield/ha was significant in high yielding mutants and the mean values for most of the traits were higher as compared to the parent DS-1. The heritability, genetic advance and genetic advance over mean were high to moderate for most of the characters. EMS 0.50% and gamma rays 300 Gy were found to be effective in increasing yield in M_3 generation. The frequency of superior M_3 families was higher with EMS 0.50% followed by gamma rays (300 Gy) for yield and yield attributing characters. Promising high yielding mutants were identified, which can be tested over different locations for yield performance.

Key words: Mutagens, gamma rays, EMS

Introduction

Sesame (*Sesamum indicum* L.) is one of the world's oldest oilseed crops. It is the 6th most important oilseed crop grown in India on an area of 2.90 m.ha. with a productivity of 332 kg/ha which is far below the world level of 389 kg/ha. The major yield constraints are instability in yield, narrow adaptability, non-synchronous maturity, low seed retention and poor harvest index. Mutation breeding will be of special significance in sesame, where narrow variability prevails for yield traits. The utilization of mutagens for enlarging variability in quantitatively inherited characters has been demonstrated in sesame (Rangaswamy, 1980). Hence, the present investigation was undertaken to assess the amount of variability induced by artificial mutagens in M_3 generation and to isolate desirable high yielding mutants.

Materials and methods

The experiment was conducted during *rabi* 2003 and *kharif* 2004 at Saidapur Farm of University of Agricultural Sciences, Dharwad which falls under zone-8 (Northern Transitional Zone) of Karnataka. Dry seeds of popular variety DS-1 were pre-soaked in water for six hours and treated with 0.50% and EMS for eight hours. The other treatment consisted of treating the seeds with physical mutagens *viz.*, 300, 400 and 500 Gy doses of gammay rays at BARC, Mumbai.

The material in M_3 generation for high yielding mutants trial consisted of 86 plants with high yield (>10g/plant) selected from M_2 generation and raised as plant to row progenies in randomized block design with two replications. Each entry was planted in three rows of 3 m with inter and intra-row spacing of 45 x 30 cm, respectively. Observations were recorded on five randomly selected plants in each entry on plant height (cm), days to 50% flowering, number of primary branches, number of capsules/plant, length of capsule (cm), days to maturity, seed yield/plot (g), 1000 seed weight (g) and oil content. The estimates of variance, genetic advance and genetic advance over mean were calculated as per Johnson *et al.* (1955), PCV and GCV as per Burton and De Vane (1953) and heritability as per Hanson *et al.* (1956).

Results and Discussion

The analysis of variance indicated highly significant variations among mutants for all the traits indicating ample variability among the genotypes.

The genetic variance for plant height was high in all the treated populations. 300 Gy recorded highest genetic variance and GCV. EMS-0.50% recorded highest heritability of 84.25% followed by 300 Gy (80%). Highest genetic advance and genetic advance over mean were recorded with 300 Gy (Table 2). The results imply that selection for plant height is efficient as revealed by Rangaswamy (1980).

The genetic variance for number of primary branches increased only in gamma rays with 400 Gy and EMS-0.50% and decreased with gamma rays with 300 Gy and 500 Gy. Highest genetic variance (0.18), GCV (14.62), genetic advance (0.74) and genetic advance over mean (25.50) were recorded with 400 Gy and higher heritability estimates of 80% was observed in EMS-0.50%. Chavan and Chopde (1982) also obtained higher heritability and genetic advance, which suggests the possible scope for exercising selection for improving number of primary branches.

Table 1 MSS of genotypes for high yielding mutants in M_3 generation

Characters	Sources of variation	MSS
Plant height (cm)	Among mutants	17434.33**
Number of primary branches	Among mutants	21.44**
Number of capsules	Among mutants	7001.37**
Capsule length (cm)	Among mutants	12.94**
Days to 50% flowering	Among mutants	4831.63**
Days to maturity	Among mutants	23605.52**
Seed yield/plant (g)	Among mutants	73.21**
Seed yield/ha (kg)	Among mutants	330040.06**
1000-grain weight (g)	Among mutants	23.86**
Oil content (%)	Among mutants	4503.73**

*,** Significant at 5% and 1% level of probability, respectively at 85 degrees of freedom for all characters

Gammay rays 500 Gy recorded highest GCV (6.19%) for days to 50% flowering. The heritability values were moderate to high in all the treated populations. The treatment 300 Gy recorded highest heritability of 48.68%. The genetic advance increased in all the populations while the genetic advance over mean was low in all the populations. The treatment 500 Gy recorded highest genetic advance (4.31) and genetic advance over mean (8.80). Ibrahim *et al.* (1983) studied 12 homozygous M_6 mutants which revealed positive relationship for number of days to flowering.

The genetic variance for number of capsules increased in all populations except 500 Gy. EMS-0.50% recorded highest genotypic variance (93.61), which was double the parental value (49.60) and GCV (16.59%). Highest heritability was recorded by Gamma rays. 300 Gy (83.60%). The irradiated populations showed similar values for genetic advance as compared to EMS-0.50% which recorded highest genetic advance (18.12) and genetic advance over mean (31.08%). Similar results were obtained by Sheeba *et al.* (2003) at 400 Krad for number of capsules/plant.

For capsule length, the genotypic variance increased in all the treated populations (Table 1). Gamma rays 500 Gy recorded highest GCV value (6.19%). The heritability values of all the treated populations for capsule length were moderate. The treatment with EMS-0.50% recorded highest heritability (62.92%) followed by 300 Gy with 61.90%. The genetic advance for all the treatments were low, however, the genetic advance over mean was highest in EMS-0.50% (47.03) followed by 500 Gy (43.71). The moderate heritability with higher genetic advance over mean indicated good scope for selection, as capsule length is a polygenic trait. The results are in confirmation with Sheeba *et al.* (2003).

Table 2 Genetic variability for different characters among selected mutants for high yield in M_3 generation of sesame

Treatment	Plant height (cm)					No. of primary branches					Days to 50% flowering				
	V_G	GCV (%)	h_2	GA	GAM (%)	V_G	GCV (%)	h_2	GA	GAM (%)	V_G	GCV (%)	h_2	GA	GAM (%)
Control	13.60	4.07	60.40	5.86	6.46	0.09	11.53	56.25	0.46	17.82	2.83	3.47	40.95	2.21	4.59
300 Gy	39.20	5.67	80.00	11.50	10.44	0.07	9.98	53.82	0.39	15.09	7.42	5.57	48.68	3.90	8.11
400 Gy	14.51	3.99	58.98	5.92	6.22	0.18	14.62	72.00	0.74	25.50	3.63	3.88	42.85	2.55	5.23
500 Gy	17.60	4.48	57.14	6.53	6.98	0.08	9.30	61.53	0.45	15.03	9.25	6.19	47.66	4.31	8.60
EMS-0.50%	18.20	4.57	84.25	8.06	8.60	0.16	12.51	80.00	0.73	23.03	7.22	5.52	44.44	3.68	7.57

Treatment	No. of capsules/plant					Capsule length (cm)					Days to maturity				
	V_G	GCV (%)	h_2	GA	GAM (%)	V_G	GCV (%)	h_2	GA	GAM (%)	V_G	GCV (%)	h_2	GA	GAM (%)
Control	49.60	13.13	75.59	12.59	23.53	0.12	14.49	44.44	0.47	19.88	5.72	2.56	55.91	3.68	3.95
300 Gy	53.72	11.60	83.68	13.80	21.98	0.26	20.39	61.90	0.82	33.05	7.68	2.78	62.43	4.51	4.52
400 Gy	61.30	15.20	74.29	13.90	26.95	0.13	14.89	54.16	0.54	22.58	6.75	2.68	59.70	4.13	4.27
500 Gy	47.91	12.80	72.91	12.17	22.50	0.60	31.23	46.15	1.08	43.71	10.62	3.51	78.51	5.94	6.42
EMS-0.50%	93.61	16.59	82.67	18.12	31.08	0.56	28.78	62.92	1.22	47.03	8.61	2.89	60.56	4.70	4.64

Treatment	Seed yield/ha					1000-seed weight					Oil content				
	V_G	GCV (%)	h_2	GA	GAM (%)	V_G	GCV (%)	h_2	GA	GAM (%)	V_G	GCV (%)	h_2	GA	GAM (%)
Control	112.60	1.08	60.40	16.96	1.82	0.27	16.08	41.53	0.68	21.35	1.72	2.83	46.61	1.84	3.99
300 Gy	128.71	1.17	52.41	17.00	1.76	0.67	23.93	55.83	1.25	36.80	4.67	4.60	48.64	3.10	6.62
400 Gy	157.63	1.21	48.13	17.97	1.73	0.43	18.89	38.05	0.83	24.01	7.21	5.65	63.52	4.40	9.28
500 Gy	165.77	1.30	45.00	17.78	1.79	0.47	19.90	33.57	0.81	23.85	8.36	6.11	54.56	4.39	9.30
EMS-0.50%	135.63	1.19	50.37	17.02	1.74	0.75	24.60	60.97	1.39	39.57	5.42	4.95	57.65	3.64	7.74

Table 3 Mean performance of high yielding mutants selected in M_3 generation of sesame

Progeny number	Treatment	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	1000-seed weight (g)	Special characters
699	EMS-0.5%	1481.4**	48.3	711.1	3.7	High seed yield
949	GR-500 Gy	1449.3**	48.5	702.9	3.4	High seed yield
450	GR-500 Gy	1449.3**	48.7	705.8	3.9	High seed yield and oil per cent
383	GR-400 Gy	1276.0**	47.7	607.4	3.9	High test weight
1022	Gr-500 Gy	1266.5**	47.6	601.6	3.3	Early maturity
1041	Gr-300 Gy	1148.1**	47.1	540.7	3.8	High test weight
965	EMS-0.5%	1135.7	48.3	548.5	3.1	High oil per cent
119	GR-300 Gy	1125.8	47.8	537.0	2.4	Medium seed yield
504	EMS-0.5%	1115.9	48.7	542.3	3.4	High oil per cent
615	GR-300 Gy	1111.1	47.2	523.3	3.5	High test weight
	Mean (DS-1)	1056.7	47.5	-	3.4	
	SEm±	40.6	0.4	-	0.2	
	CD (P=0.05)	81.5	2.2	-	NS	
	CV (%)	14.6	5.6	-	9.2	

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

The GCV values for days to maturity were low among all the populations with 500 Gy recording the highest GCV of 3.51%. Heritability values were moderate to high while the genetic advance and genetic advance over mean had low values among all the populations. Gamma rays 500 Gy recorded highest genetic advance (5.94) and genetic advance over mean (6.42%). The mean number of days to maturity was less in gamma rays with 500 Gy compared to any other treatments. Chavan and Chopde (1982) also obtained early mutants with gamma rays.

Yield performance showed increase in genotypic variance for all the treated populations (Table 3). 500 Gy recorded highest GCV (1.30). The heritability values were moderate to high when compared to control, recording highest values of 60.40%. However, among the treated populations 300 Gy had highest heritability values (52.41%). The genetic advance was higher in 400 Gy (17.97), while the highest genetic advance over mean was noticed in control treatment (1.82) followed by 500 Gy (1.79). Sheeba *et al.* (2003) obtained maximum heritability for single plant yield in EMS-1.0% treated progenies and recommended selection based on seed yield when heritability is high.

1000-seed weight registered increase in genotypic variance in all the treated populations. The heritability values were moderate to high among the treated populations, indicating scope for artificial selection for seed size, while the genetic advance values were low. EMS-0.50% recorded highest GCV (24.60%), heritability (60.97%), genetic advance (1.39) and genetic advance over mean (39.57%) among the treated populations. Rangaswamy (1980) observed decrease in mean for 1000-seed weight in M_2 and M_3 generations.

The treatment, 500 Gy recorded the highest genotypic variance (8.36) and GCV (6.11%) for oil content. Highest heritability value of 63.52% was noticed in treatment 400 Gy. The values of genetic advance and genetic advance over mean for 400 Gy and 500 Gy were on par with each other. 400 Gy recorded higher genetic advance (4.40), while 500 Gy recorded higher genetic advance over mean (9.30%). Rangaswamy (1980) observed decrease in mean value for oil content in M_2 and M_3 generation, while Kamal and Sasikala (1985) obtained high yielding mutants, which had 5-13% higher oil content through gamma irradiation.

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

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Abstract

Line x Tester analysis in sesame using four lines and three testers was carried out to study the combining ability and heterosis for yield and its attributes *viz.*, days to maturity, plant height, number of primary branches/plant, number of capsules on the main axis, number of capsules/plant, length of capsule, number of seeds/capsule, 1000-seed weight and seed yield/plant. General and specific combining ability (*gca* and *sca*) variances showed major contribution of additive gene action for all the nine characters studied except number of seeds/capsule. Lines TC-289 and T-4 were good general combiners for most of the characters including seed yield/plant. Highest magnitude of standard heterosis was recorded in the cross TC-289 x ES-3. Other promising crosses for high yield were T-4 x ES-3, TC-289 x GT-1 and TC-289 x JLT-8 on the basis of sca effect. Heterosis and *per se* performance may be used to select crosses for exploitation of heterosis in sesame.

Key words: *Heterosis, Sesame indicum*, combining ability

Introduction

Sesame, *Sesamum indicum* L. is an important oilseed crop in the tropical and subtropical regions. India ranks first in the world in sesame cultivation (27.7 % area) but its productivity is quite low (3.68 q/ha) as compared to world's (4.89 q/ha) (FAO, 2004). For breaking the present yield barrier and evolving varieties with high yield potential, it is desirable to combine the genes from genetically diverse parents. The success in identifying such parents mainly depends on the gene action that controls the trait under improvement, combining ability and genetic makeup. There are several techniques for evaluating the varieties or strains in terms of their combining ability and genetic make up. Of these, diallel, partial diallel and line x tester techniques are in common use. In the present study, 4 lines, 3 testers and their 12 crosses were evaluated for combining ability and heterosis for yield and its components.

Materials and methods

The present investigations were conducted during rainy season of 2003 at the Agriculture Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Three testers (*viz.*, JLT-8, GT-1 and ES-3) and four lines of varying agronomic and morphological characteristics (*viz.*, T-4, T-12, TC-25 and TC-289) were crossed during 2002 to produce 12 F_1s.

Test material was raised in a Randomized Block Design with three replications. Seeds of each cross and their parents were sown in a row of 4 m in length in each replication with a spacing of 45 cm between the rows and 15 cm between plants. *Observations were recorded on 10* plants selected at random in each replication for nine important characters *viz.*, days to maturity, plant height, number of primary branches/plant, number of capsules on the main axis, *number of capsules/plant, length of* capsule, number of seeds/capsule, 1000-seed weight and seed yield/plant. Combining ability analysis was done following standard procedure of Kempthorne (1957). Relative heterosis, heterobeltiosis and standard *heterosis* were estimated following the methods suggested by Hays *et al.* (1955). Variety TC-25 was used as the standard parent (check).

Results and discussion

The variances due to crosses, lines, testers and line x tester were significant for all the characters except plant height and number of seeds/capsule for lines, number of seeds/capsule for testers and seed yield/plant for line x tester (Table 1). The significant variances due to lines, testers and line x tester showed the involvement of both additive and non-additive gene actions in controlling the *traits*. However, all these characters except number of seeds/capsule appeared to be controlled predominantly by additive gene action as judged from the high GCA variance compared to SCA variance. For number of *seeds/capsule, the estimate of sca* was higher than the *gca* indicating the predominance of non-additive gene action for this trait. Similar reports have been reported by Babu *et al.* (2004) and Vidhyavathi *et al.* (2005).

A perusal of gca effects revealed that among the lines, TC-289 and T-4 were good general combiners for seed yield and its components with highly significant *gca* effects for these traits. Among the testers, ES-3 was good general combiner for seed yield/plant, number of capsules/plant and number of seeds/capsule while JLT-8 was good combiner for days to maturity, number of primary branches/plant, number of capsules on main axis, number

of capsules/plant and length of capsule. As regards to earliness, TC-25, GT-1 and T-4 were found to be the best general combiners (Table 2).

The performance of the F_1s derived from crosses T-4 x GT-1, TC-25 x JLT-8 and T-12 x JLT-8 showed better performances for early maturity. The F_1s derived from T-12 x ES-3 and TC-289 x JLT-8 for number of capsules on main axis and number of capsules/plant, F_1s from TC-25 x ES-3 for number of seeds/capsule and length of capsule, showed significant positive *sca* effects. Similarly crosses between T-12 x GT-1 and TC-289 x ES-3 for 1000-seed weight and T-4 x ES-3 for seed yield/plant were good specific combiners. Therefore, the parents, whose *per se* performance was good, were not necessarily good general combiners. Thus, for selecting good parents, both *per se* performance and *gca* effects of the parents may be more realistic. Similarly, best F_1s on the basis of *per se* performance were not in accordance to F_1s with respect to sca effects. It is observed that all the parents were not good general combiners for all the traits but when they were crossed with good general combiners, their *sca* effects were high, e.g., T-12 x ES-3 for number of capsules/plant. Similarly, low x low combiners gave significant *sca* effects though they were not good general combiners, e.g., the performance of F_1s from the cross T-12 x ES-3 for numbers of capsules on the main axis.

Heterosis was calculated as percent increase and decrease over mid-parent, corresponding better parent and standard parent (Table 3). Five crosses *viz.*, TC-25 x ES-3, TC-25 x GT-1, TC-25 x JLT-8, T-4 x GT-1 and T-4xES-3 recorded significant negative heterosis, heterobeltiosis and standard heterosis for maturity. Similar results were reported by Sankar and Kumar (2001). All the 12 crosses showed significant negative heterosis over standard check displaying dominance for earliness. The range of standard heterosis for seed yield/plant was -11.74 to 29.78% and found maximum in the cross TC-289 x ES-3. The same cross had a high heterotic value for four other traits *viz.*, number of capsules on the main axis, number of capsules/plant, number of seeds/capsule and 1000-seed weight. Heterotic behaviour of crosses with respect to yield and component traits differs from character to character. However, a few crosses such as, T-4 x ES-3, TC-289 x GT-1 and T-4 x GT-1 showed appreciable level of promising hybrid vigor for seed yield as well as over other major component traits. These findings got support from the views of earlier workers, Mishra and Yadav (1996), Solanki and Gupta (2000), Sankar and Kumar (2001), Senthil *et al.* (2003) and Singh *et al.* (2005) regarding the heterosis in sesame.

Best three parents on the basis of per se performance and gca effect and best three crosses with respect to their per *se* performance, *sca* effects and standard heterosis have been presented in Table 4. The crosses showed significant *sca* effects and heterosis for yield/plant, in which both the parents were good general combiners that produced high *sca* effects indicating the predominance of additive gene interactions e.g., the performance of the cross T-4 x ES-3. Whereas other superior crosses, where both the parents were not good general combiners showed the involvement of non-additive types of gene action. The crosses that exhibited high heterosis for seed yield and its contributing traits (TC-289 x ES-3, T-4 x ES-3 TC-289 x GT-1 and TC-289 x JLT-8) could be used fo commercial exploitation of heterosis in sesame.

Table 1 Analysis of variance for combining ability in sesame

Source	d.f.	Mean sum of squares								
		Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of capsules on the main axis	No. of capsules/ plant	Length of capsule (cm)	No. of seeds/ capsule	1000-seed weight (g)	Seed yield/plant (g)
Crosses	11	18.05**	516.26**	0.665**	72.20**	181.11**	0.2457**	51.77**	0.162**	9.74**
Lines	3	34.41*	641.26	1.023*	137.70**	344.96**	0.28*	75.95	0.25*	21.76**
Testers	2	36.87*	1336.45*	1.53*	168.86**	416.365**	0.79**	103.57	0.421**	17.96**
Line x Tester	6	3.6*	180.40**	0.197*	7.23**	20.77**	0.048**	22.41**	0.033**	1.00
Error	36	0.45	24.20	0.07	1.30	1.32	0.0068	2.89	0.0043	0.37
σ^2GCA	-	3.05	77.0	0.05	13.91	34.28	0.05	6.41	0.03	1.80
σ^2 SCA	-	1.05	52.1	0.042	1.98	6.48	0.014	6.51	0.01	0.21
σ^2A	-	6.10	154.0	0.10	27.82	68.55	0.093	12.83	0.06	3.60
σ^2D	-	1.05	52.10	0.042	1.98	6.48	0.014	6.51	0.01	0.21
σ^2D/ σ^2A	-	.17	0.34	0.42	0.07	0.10	0.15	0.51	0.175	0.06

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

Table 2 Estimates of general combining ability (*gca*) and specific combining ability (*sca*) effects in sesame

Parents	Days to maturity	Plant height (cm)	No. of primary branches/ plant	No. of capsules on the main axis	No. of capsules/ plant	Length of capsule (cm)	No. of seeds/ capsule	1000- seed weight (g)	Seed yield/ plant (g)
Lines									
TC-289	0.61**	7.89**	-0.241**	1.11**	1.78**	0.233**	3.03**	0.202**	1.99**
T-12	2.39**	-11.44**	0.114	-1.44**	-2.67**	-0.059*	-0.86	-0.047**	-1.49**
TC-25	-2.17**	4.45*	-0.30**	-4.44**	-6.78**	-0.15**	-3.64**	0.043	-0.93**
T-4	-0.83**	-0.89	0.425**	4.78**	7.67**	-0.133**	1.47**	-0.195**	0.42*
SE(gi)	0.22	1.64	0.088	0.38	0.38	0.028	0.57	0.022	0.203
SE (gi-gi)	0.32	2.32	0.125	0.54	0.54	0.039	0.080	0.027	0.287
Testers									
JLT-8	1.69**	-11.11**	0.381**	3.70**	5.36**	0.231**	-3.27**	-0.189**	-1.10**
GT-1	-1.81**	9.89**	-0.052	-3.80**	-6.31**	0.044	0.86	0.185**	-0.22
ES-3	0.11	1.22	0.327**	0.11	0.94**	-0.276**	2.41**	0.005	7.01**
SE(gj)	0.20	1.42	0.076	0.33	0.33	0.024	0.49	0.019	0.176
SE (gj-gj)	0.27	2.01	0.11	0.47	0.47	0.034	0.69	0.027	0.248
Crosses									
TC-289 x JLT-8	0.29	-1.89	0.007	1.64*	3.64**	0.089	-2.26*	-0.017	-0.08
TC-289 x GT-1	-0.523	-0.89	-0.06	-1.20	-2.03**	-0.081	1.61	-0.072	0.05
TC-289 x ES-3	0.223	2.78	0.048	-0.44	-1.61*	-0.006	0.66	0.085*	0.04
T-12 x JLT-8	-0.823*	-0.56	0.16	-1.48*	-2.58**	0.086	1.89	-0.051	-0.18
T-12 x GT-1	0.363	1.11	0.09	-0.313	0.423	0.053	1.70	0.127**	0.64
T-12 x ES-3	0.443	-0.56	-0.24	1.78*	2.17**	-0.139**	-3.59**	-0.09*	-0.48
TC-25 x JLT-8	-0.93**	-9.45**	-0.37	0.853	0.863	-0.171**	-3.19**	-0.011	0.23
TC-25 x GT-1	1.34**	5.22	-0.20	0.353	0.87	0.082	-2.79**	0.054	0.093
TC-25 x ES-3	-0.33	4.22	0.175	-1.223	-1.72**	1.09**	2.99**	-0.046	-0.32
T-4 x JLT-8	1.40**	11.89**	0.213	-1.03	-1.92**	-0.002	0.563	0.0723	0.02
T-4 x GT-1	-1.083**	-5.44	-0.22	1.133	0.75	-0.055	-0.50	-0.12**	-0.73*
T-4 x ES-3	-0.34	-6.44*	0.021	-0.11	1.17	0.06	-0.05	0.041	0.75*
SE (Sij)	0.387	2.84	0.153	0.658	0.663	0.048	0.98	0.038	0.35
SE (Sij-Sij)	0.548	4.02	0.216	0.93	0.94	0.067	1.39	0.054	0.50

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

Table 3 Heterosis (in per cent) over mid parent (h_1), better parent (h_2) and standard variety TC-25 (h_3) for different characters in sesame

Crosses	Heterosis (in percent) over	Days to maturity	Plant height (cm)	No. of primary branches/ plant	No. of capsules on the main axis	No. of capsules/ plant	Length of capsule (cm)	No. of seeds/ capsule	1000 seed weight (g)	Seed yield/pant (g)
TC-289 x JLT-8	H_1	4.08**	-0.63	2.37	15.32**	7.91**	8.40**	-4.43*	1.00	3.98
	H_2	1.59	-6.33	0.00	3.69	1.95**	6.54**	-10.96**	-6.62**	-8.40**
	H_3	-2.30**	-9.54	8.90	26.96**	15.44**	25.27**	3.13	1.6	12.55**
TC-289 x GT-1	H_1	0.42	8.54**	-12.43*	2.49	-0.76	0.33**	3.76*	11.94**	13.51**
	H_2	-3.59**	6.72**	-13.62*	-5.76	-5.76	-4.67*	0.20	5.15**	-2.82
	H_3	-7.28**	3.05	-5.93	-7.89*	-7.89*	12.09**	16.10**	14.40**	19.40**
TC-289 x ES-3	H_1	1.62**	2.84	-21.10**	11.63**	5.95**	-1.05	5.03**	2.16	10.23**
	H_2	-0.40*	1.94	-23.66*	10.34**	4.02**	-12.15**	1.03	0.0	5.63*
	H_3	-4.22**	0.19	-10.98	7.85*	4.78**	3.30	17.02**	13.60**	29.78**
T-12 x JLT-8	H_1	3.84**	-4.98*	24.48**	-9.43**	-6.31**	8.51**	2.28	-6.61**	-10.90**
	H_2	0.40*	-6.25*	19.14**	-11.92**	-8.44**	4.81**	1.04	-10.67**	-15.51**
	H_3	-1.53*	-19.85**	23.74**	7.85*	3.67**	19.05**	3.55	-9.6**	-11.74**
T-12 x GT-1	H_1	2.67**	-5.51**	8.42	-12.48**	-6.58**	4.84*	4.55*	14.23**	3.96
	H_2	-2.34**	-0.20	2.80	-25.23**	-12.93**	4.84*	1.95	11.07**	-4.48
	H_3	-4.22**	-6.87**	8.90	-13.48	-5.89**	10.99*	9.96**	12.40**	-0.20
T-12 x ES-3	H_1	3.02**	-3.89	-13.04*	1.09	1.43	-6.32**	-0.83	-9.87**	-5.44*
	H_2	0.0	-11.27**	-12.12**	-7.75**	-3.74**	-12.80**	-2.93	-14.79**	-8.86**
	H_3	-1.92**	-12.79**	-8.01	6.74*	4.04*	-7.70**	3.88	-3.2	2.65
TC-25 x JLT-8	H_1	-2.80**	-9.26**	-5.97	-5.06*	-3.46**	-4.29*	-4.30*	-0.62	-2.03
	H_2	-6.89**	-15.84**	-7.71	-13.76**	-10.10**	-10.00**	-4.30	-4.4*	-5.16
	H_3	-6.90**	-15.84**	-4.15	5.59	2.93**	2.20**	-4.30	-4.4*	-5.16
TC-25 x GT-1	H_1	-2.84**	8.19**	-2.88	-13.59**	-6.84**	1.42	-5.54**	15.75**	6.51*
	H_2	-8.43**	4.58	-5.60	-21.37**	-9.93**	-1.38	-8.98**	13.20**	-0.14
	H_3	-8.43**	4.58	0.0	-21.37**	-9.93**	4.40	-1.82**	13.20**	-0.14
TC-25 x ES-3	H_1	-4.38**	-0.10	-15.07*	-11.48**	-3.36**	2.68	1.61**	-4.49*	1.15
	H_2	-8.05**	-0.96	-21.12**	-13.48**	-4.79**	-6.96**	2.81	10.21**	-4.52
	H_3	-8.05**	-0.96	-8.01	-13.48**	-4.79**	-6.96**	10.01**	2.0	7.46*
T4 x JLT-8	H_1	2.01**	8.91**	25.83**	12.64**	6.06**	4.95*	1.50	-2.19	2.58
	H_2	-1.92**	8.67**	22.43**	6.64*	2.27*	-4.19	-1.91	-3.46	-3.57
	H_3	-2.68**	-6.68**	34.42**	30.33**	15.81**	8.80**	5.17*	-10.80**	2.58
T-4 x GT-1	H_1	-3.67*	6.50**	0.96	17.68**	6.67**	0.18	2.40	4.31	6.51*
	H_2	-9.26**	2.25	-0.81	3.10	0.70	-5.54	-0.90	1.26	-2.93
	H_3	-9.57**	-4.58	8.90	12.34**	5.88**	0.0	10.12**	-3.2	3.26
T4 x ES-3	H_1	-2.40**	-2.39	-4.85	18.69**	13.10**	0.20	5.83**	-5.70**	13.20**
	H_2	-5.80**	-8.55**	-7.64	11.35**	8.75**	-1.17	5.72**	-15.50**	10.10**
	H_3	-6.52**	-10.12**	7.72	21.34**	14.34**	27.33**	13.35**	-4.0	23.95**
CD (P=0.05)	H_1	0.95	7.06	0.39	1.64	1.64	0.12	2.44	0.09	0.87
CD (P=0.01)	H_1	1.28	9.47	0.52	2.20	2.20	0.16	3.26	0.13	1.17
CD (P=0.05)	H_2 & H_3	1.12	8.16	0.44	1.89	1.91	0.14	2.82	0.11	1.02
CD (P=0.01)	H_2 & H_3	1.50	10.3	0.59	2.53	2.56	0.18	3.78	0.15	1.36

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

Table 4 Three best parents, F_1s, general combiners and specific combiners for yield and component traits in sesame in line x tester

	Days to maturity		Plant height		No. of primary branches/ plant	No. of capsules on the main axis	No. of capsules/ plant	Length of capsule	No. of seeds/ capsule	1000-seed weight	Seed yield/ plant
	Early	Late	Tall	Dwarf							
Best parent (*per se* performance)	GT-1 JLT-8 ES-3	TC-25 T-4 T-12	TC-25 ES-3 TC-289	T-12 JLT-8 T-4	ES-3 T-4 TC-289	JLT-8 T-12 T-4	JLT-8 T-12 T-4	TC-289 JLT-8 GT-1	TC-289 GT-1 T-4	ES-3 TC-289 T-12	TC-289 ES-3 T-4
Best general combiners (*gca*)	TC-25 GT-1 T-4	T-12 JLT-8 TC-289	GT-1 TC-289 TC-25	T-12 JLT-8 T-4	T-4 JLT-8 T-12	T-4 JLT-8 TC-289	T-4 JLT-8 TC-289	TC-289 JLT-8 GT-1	TC-289 ES-3 T-4	TC-289 GT-1 TC-25	ES-3 TC-289 T-4
Best F_1s with respect of *sca*	T-4xGT-1 T-12xJLT-8 TC-25xJLT-8	T-4xJLT-8 TC-25xGT-1 T-12xES-3	T-4xJLT-8 TC-25xGT-1 TC-25xES-3	TC-25xJLT-8 T-4xES-3 T-4xGT-1	T-4xJLT-8 TC-25xES-3 T-12xJLT-8	T-12xES-3 TC-289xJLT-8 T-4xGT-1	TC-289xJLT-8 T-12xES-3 T-4xES-3	TC-25xES-3 TC-289xJLT-8 T-12xJLT-8	TC-25xES-3 T-12xJLT-8 T-12xGT-1	T-12xGT-1 TC-289xES-3 TC-25xGT-1	T-4xES-3 T-12xGT-1 TC-25xJLT-8
Best F_1s with respect to *per se* performance and standard heterosis	T-4xGT-1 TC-25xGT-1 TC-25xES-3	TC-289xJLT-8 TC-289xES-3 T-12xJLT-8	TC-25xGT-1 TC-289xGT-1 TC-289xES-3	T-12xJLT-8 TC-25xJLT-8 T-12xES-3	T-4xJLT-8 TC-289xJLT-8 T-4xES-3	T-4xJLT-8 TC-289xJLT-8 T-4xES-3	T-4xJLT-8 TC-289xJLT-8 T-4xES-3	TC-289xJLT-8 T-12xJLT-8 TC-289xGT-1	TC-289xES-3 TC-289xGT-1 T-4xES-3	TC-289xGT-1 TC-289xES-3 TC-25xGT-1	TC-289xES-3 T-4xES-3 TC-289xGT-1

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Variability and character association analysis in sesame, *Sesamum indicum* L.

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Abstract

Sixty two sesame genotypes were evaluated during *kharif*, 2002 for genetic diversity in respect of nine quantitative characters. Analysis of variance revealed significant differences among genotypes for all the nine characters studied. High GCV and PCV were observed for seed yield/plant, number of capsules/plant, number of primary branches, number of seeds/capsule and plant height. High heritability and genetic advance as per cent mean was observed for seed yield, number of capsules/plant, number of primary branches, number of seeds/capsule, plant height and days to 50% flowering. Seed yield/plant showed significant and positive association with plant height, number of capsules/plant, capsule length, number of seeds/capsule and number of primary branches. Path coefficient analysis revealed maximum positive direct effect of number of capsules on seed yield followed by capsule length and plant height.

Key words: Genetic variability, character association, sesame

Introduction

Sesame is an important oilseed crop of tropical and sub-tropical region. The success of any crop improvement programme essentially depends on the nature and magnitude of the genetic variability present in the crop. The knowledge of nature and magnitude of genetic variability is of immense value for planning efficient breeding programme to improve the yield potential of the genotypes. Information on the association of plant characters with seed yield is of great important to a breeder in selecting desirable genotypes. Since, the information on these aspects is limited, the present investigation was carried out to gather information on variability, characters association and path coefficient analysis in 62 genotypes of sesame for nine characters.

Materials and methods

The material for the study comprised of 62 sesame genotypes representing diverse eco-geographic origin. The experiment was conducted at College of Agriculture, Dharwad during *kharif*, 2002 in a Randomized Block Design with three replications. Each genotype was sown in a single row of 4 m length at a distance of 30 cm between the rows and 10 cm between the plants within the rows. Five plants in each row were selected at random and the data on nine characters were recorded. Phenotypic and genotypic components of variances were worked out based on the formula given by Lush (1940). Heritability in the broad sense was derived based on the formula given by Hanson *et al.* (1956). Genetic advance was obtained by the formula prescribed by Johnson *et al.* (1955). The method adopted by Burton and Devane (1953) was used to calculate phenotypic and genotypic coefficients of variation. The genotypic and phenotypic correlation coefficients were worked out by following Al-Jibouri *et al.* (1958) and path coefficient analysis as suggested by Dewey and Lu (1959).

Results and discussion

The analysis of variance revealed significant differences among the genotypes for seed yield and component characters indicating considerable amount of genetic variation in the material. The phenotypic and genotypic coefficients of variation (Table 1) were highest for seed yield/plant, number of capsules/plant, number of primary branches and number of seeds/capsule, suggesting that these characters are under the influence of genetic control. Hence, these characters can be relied upon simple selection can be practiced for further improvement. These results are in consonance with those of Patil and Sheriff (1966) and Reddy *et al.* (2001). Moderate PCV and GCV values were recorded for plant height, days to 50% flowering and capsule length. The results are in confirmity with the findings of Chandrashekhara and Reddy (1993) and Reddy *et al.* (2001). Oil content and days to maturity recorded a low phenotypic and genotypic coefficients of variation. Similar results were reported by Pathak and Dixit (1992), Chandrashekhara and Reddy (1993) and Shadakshari *et al.* (1995).

High heritability coupled with high genetic advance was observed for seed yield/plant, number of capsules/plant, number of primary branches, number of seeds/capsule, plant height and days to 50% flowering. This indicates the lesser influence of environment in expression of these characters and prevalence of additive gene action in their inheritance hence, amenable for simple selection. Similar results were reported by Reddy *et al.* (2001) and

Krishnaiah *et al.* (2002). High heritability with moderate genetic advance was recorded for days to maturity and capsule length indicating that the character was also governed by both additive gene action. These results are in accordance with Krishnaiah *et al.* (2002). High heritability coupled with low genetic advance was recorded for oil content indicating non-additive gene action. These results are in confirmity with the findings of Reddy *et al.* (2001).

Genotypic correlation in general was higher than the phenotypic correlation (Table 2 and 3) indicating a less influence of environmental factors. Plant height exhibited significant positive association with seed yield/plant. Similar association was observed by Pawar *et al.* (2002). Significant positive correlation between number of capsules and yield/plant indicated that this trait was a reliable indicator. Tomar *et al.* (1999) also found similar observations. Capsule length, number of seeds/capsule and number of primary branches exhibited significant correlation with seed yield/plant.

The results of path coefficient analysis revealed (Table 4) that the number of capsules/plant had maximum positive direct effect on seed yield/plant followed by capsule length and plant height. Therefore, these traits may be considered as the principal traits while selecting for seed yield. In other words, selection indices may be formed by considering all these characters for improvement of seed yield.

Table 1 Genetic parameters for nine quantitative characters in sesame

Characters	Range		Mean	Variance		Coefficient of variability		Broad sense heritability (%) (h^2)	Expected genetic advance at 5% (GA)	Genetic advance per cent mean (GAM)
	Min.	Max.		Genotypic	Phenotypic	Genotypic (GCV)	Phenotypic (PCV)			
Days to 50% flowering	30.0	53.7	42.5	45.2	46.1	15.8	15.9	98.0	13.7	32.3
Days to maturity	74.0	114.7	86.0	82.4	83.2	10.6	10.6	99.0	18.6	21.7
Plant height	60.4	124.0	80.0	246.5	265.7	19.6	20.4	92.8	31.2	38.9
Number of primary branches	0.3	5.0	2.6	0.6	0.6	29.0	31.0	87.8	1.4	56.0
Number of capsules/plant	22.7	100.1	43.4	342.6	355.5	42.6	43.4	96.4	37.4	86.2
Capsule length	1.9	3.1	2.3	0.1	0.1	10.8	12.2	78.0	0.5	19.7
Number of seeds/capsule	39.9	102.5	63.7	189.8	225.4	21.6	23.6	84.2	26.1	40.9
Oil content	48.3	52.3	50.7	0.7	0.8	1.6	1.8	80.0	1.5	2.9
Seed yield/plant	2.1	14.5	4.3	6.9	6.7	59.7	60.1	98.7	5.3	122.1

Table 2 Genotypic correlation coefficients between seed yield and its components in sesame

Characters	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches	Number of capsules/ plant	Capsule length	Number of seeds/ capsule	Oil content	Seed yield/plant
Days to 50% flowering	1.000	0.579**	0.092	0.011	0.087	0.165	0.148	0.012	0.111
Days to maturity		1.000	0.121	-0.001	0.109	0.242	0.235	0.047	0.120
Plant height			1.000	0.325**	0.998**	0.317*	0.330**	0.193	0.785**
Number of primary branches				1.000	0.334**	-0.139	-0.113	-0.002	0.328**
Number of capsules/plant					1.000	0.329**	0.341**	0.201	0.784**
Capsule length						1.000	1.007**	0.052	0.340**
Number of seeds/capsule							1.000	0.055	0.331**
Oil content								1.000	0.202
Seed yield/plant									1.000

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

Table 3 Phenotypic correlation coefficients between seed yield and its components in sesame

Characters	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches	Number of capsules/ plant	Capsule length	Number of seeds/ capsule	Oil content	Seed yield/plant
Days to 50% flowering	1.000	0.571**	0.092	0.009	0.087	0.139	0.133	0.002	0.110
Days to maturity		1.000	0.116	-0.001	0.106	0.210	0.209	0.046	0.119
Plant height			1.000	0.305*	0.988**	0.287*	0.309*	0.165	0.778*
Number of primary branches				1.000	0.318*	-0.101	-0.092	-0.008	0.314*
Number of capsules/plant					1.000	0.289*	0.314*	0.174	0.784**
Capsule length						1.000	0.971*	0.044	0.300*
Number of seeds/capsule							1.000	0.067	0.305*
Oil content								1.000	0.180
Seed yield/plant									1.000

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

Table 4 Direct (diagonal) and indirect effects of eight characters on seed yield/plant at phenotypic level in sesame

Characters	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches	Number of capsules/ plant	Capsule length	Number of seeds/ capsule	Oil content	Phenotypic correlation with seed yield
Days to 50% flowering	0.031	0.001	0.015	0.001	0.048	0.041	-0.028	0.000	0.110
Days to maturity	0.018	0.002	0.019	0.000	0.059	0.062	-0.043	0.0003	0.119
Plant height	0.003	0.000	0.165	0.030	0.550	0.085	-0.064	0.009	0.778
Number of primary branches	0.000	0.000	0.050	0.098	0.177	-0.030	0.019	0.000	0.314
Number of capsules/plant	0.003	0.000	0.163	0.031	0.557	0.086	-0.065	0.010	0.784
Capsule length	0.004	0.000	0.047	-0.010	0.161	0.296	-0.201	0.002	0.300
Number of seeds/capsule	0.004	0.000	0.051	-0.009	0.175	0.287	-0.208	0.004	0.305
Oil content	0.000	0.000	0.027	-0.001	0.097	0.013	-0.014	0.057	0.180

Residual = 0.3655

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Inheritance of quantitative characters in linseed, *Linum usitatissimum* L.

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Abstract

Six genetic populations *viz.*, P_1, P_2, F_1, F_2, BC_1 and BC_2 of eight crosses involving 12 parents were evaluated to estimate the nature and magnitude of gene action, their heterotic response and inbreeding depression for seven quantitative characters during *rabi*, 2001.The results on gene action and mean analysis showed that all the three types of gene actions i.e., additive, dominance and epistatic were responsible in varying proportions for all the crosses of seven characters. Among the epistatic interaction dominance x dominance was more important followed by additive x additive effects. Studies on heterosis indicated that dominance was largely responsible for high level of heterotic effects. Under such a genetic situation it was suggested that reciprocal recurrent selection or mass selection with recurrent random mating might be most efficient for utilization of all three types of gene effects.

Key words: Linseed, *Linum usitatissimum*, generation mean analysis, gene action, quantitative characters

Introduction

An understanding of the mode of inheritance of complex quantitative characters is essential for formulation of any effective selection procedure for improvement of a particular trait. The estimates of gene effects help in understanding the genetic potentiality of the population. The present investigation was undertaken to study the gene effects, heterosis and inbreeding depression for seven characters in linseed.

Materials and methods

Three experiments, consists of 6 genetic population *viz.*, P_1, P_2, F_1, F_2, BC_1 and BC_2 were laid out in a Randomized Complete Block Design with three replications at Research Farm of C.S. Azad University of Agriculture and Technology, Nawabganj, Kanpur during *rabi* 2001-02. The F_1 and parents were sown in single row each whereas, backcross and F_2 populations were sown in three and six rows, respectively, in three meter length at a row spacing of 30 cm. Observations for seven traits in each replication were recorded on 10 randomly selected plants from parents and F_1s, 20 plants from backcrosses (BC_1 and BC_2) and 30 plants form F_2 generation. Six genetic parameters were estimated according to Hayman (1958).

Results and discussion

The additive gene effect (d) was significant but lower in magnitude as compared to dominance (h) for all the traits except 100 seed weight, where dominance gene effect was higher than additive.

The dominance gene effect (h) was found to be significant for the inheritance of days to 50% flowering in crosses RL 993 x Janki, Neelum x Ayogi and Chambal x Ayogi; for plant height in crosses Neelum x Ayogi, Chambal x Ayogi Nagarkot x Neela; for number of primary branches in crosses Neelum x Ayogi, RL 993 x JRF 5 and RL 993 x Janki; for number of capsules/plant RL 993 x JRF 5, Nagarkot x Neela and Nagarkot x J-23; for days to maturity, Nagarkot x J-23, Neelum x Ayogi and RL 993 x JRF 5 and for seed yield/plant (g) in crosses Neelum x Ayogi, KL 187 x Hira and Chambal x Ayogi.

Among the non-allelic interactions, additive x additive (l) contributed much to the inheritance of days to 50% flowering in crosses of Chambal x Ayogi and RL 993 x Janki;p plant height in crosses of Chambal x Ayogi, Nagarkot x Neela and RL 993 x Janki; number of primary branches/plant in crosses of RL 993 x JRF 5, RL 993 x Janki, Chambal x ES-44 and Nagarkot x J-23; number of capsules/plant in crosses of RL 993 x JRF 5, Nagarkot x Neela and Nagarkot x J-23; days to maturity in crosses of Nagarkot x J-23, RL 993 x JRF 5 and Neelum x Ayogi; seed yield/plant (g) for Neelum x Ayogi, KL 178 x Hira. Additive x additive (l) interaction was relatively higher in all the characters except 1000-seed weight. The total absolute magnitude of l, j, l interactions were found to be less than the mean effect in most of the crosses.

Duplicate type of epistatis was more pronounced than the complementary type for days to 50% flowering, plant height, number of primary branches/plant, number of capsules/plant, days to maturity and seed yield/plant.

The estimate of gene effects showed that in all the crosses, additive gene effect (d) had significant contribution in the inheritance of days to maturity and 1000 seed weight in all the crosses. On the other hand, dominance gene effect (h) was equally important for days to maturity, number of capsules/plant, number of primary branches/plant and plant height in most of the crosses.

The contribution of dominance gene effect was even larger than the additive gene effect. The presence of epistatic gene effect were observed in all the characters considering the individual digenic epistasis; dominance x dominance (l) effect followed by additive x additive (l) and additive x dominance (j) effects contributed maximum gene interactions. The sign of dominance x dominance (l) interaction varied (plus or minus) depending upon the diminishing or enhancing effect due to the presence of duplicate or complementation effects. However, complementations of the genes were observed for these traits as also observed by Tak and Gupta (1989), Singh (2000) and Rao *et al.* (2001).

The presence of epistasis can not be ignored, while formulating an effective breeding programme. Therefore, estimation of only the main gene effects and formulating a breeding programme presuming that epistasis is absent or negligible is likely to be not only misleading but also vitiate the estimates of genetic variation. Wright (1935) reported that any character is affected by all the genes in a genome hence it would be unrealistic to assume that inter-allelic interaction would be absent.

The F_1 in fact, would express the average effect of all the polygenes which may be interacting at the allelic as well as non-allelic level and the non-allelic interaction of complementary would tend to depress the regression of the progeny means on the parental values by causing the genotypic variance to be greater due to additive variance (Panse and Sukhatme, 1961). The results in breeding depression and heterosis suggested that the characters, number of primary branches/plant, days to maturity and seed yield/plant showed useful heterosis which might be due to the presence of dominance effects (h) (Table 1). It was found that all the characters showed less reduction in vigour in F_2 generation. The degree of inbreeding depression depends upon the contribution of additive gene effects.

On the basis of present study, when all the three types of gene action *viz.*, additive, dominance and epistatic played a vital role in the expression of quantitative characters. Biparental mating in early generation followed by reciprocal recurrent selection should be more appropriate to break the gene constitution and so release the free variability for the traits.

Table 1 Estimation of gene effect based on six parameter model for 7 characters in linseed

Character	Crosses	m	d	h	l	j	i	Type of epistasis
Days to 50% flowering	KL 178 x Hira	81.00** ±0.58	-0.33 ±0.66	-1.83 ±2.75	-7.33** ±2.67	-0.83 ±0.78	-12.33** ±3.80	C
	Nagarkot x Neela	77.33** ±0.33	1.00* ±0.47	2.17 ±02.00	2.00 ±1.63	1.83 ±1.11	-1.67 ±3.28	D
	Nagarkot x J-23	78.00** ±6.00	-3.33** ±0.47	-8.00** ±1.01	-8.00** ±0.94	-4.75** ±0.50	13.00** ±2.03	D
	RL 993 x Janki	73.33** ±6.67	6.00** ±0.47	21.33** ±3.15	20.00** ±2.83	7.67** ±1.35	-24.00** ±4.29	D
	RL 993 x JRF 5	83.33** ±0.33	2.00* ±0.94	8.17** ±2.32	8.00** ±2.31	1.83 ±0.96	-21.67** ±4.01	D
	Neelum x Ayogi	82.67** ±0.67	-6.00** ±0.74	16.67** ±3.06	10.67** ±3.06	4.67** ±0.78	-32.00** ±4.03	D
	Chambal x Ayogi	74.00** ±6.00	-0.33 ±0.75	20.33** ±2.14	26.00** ±1.49	1.67 ±1.67	-43.33** ±4.28	D
	Chambal x ES-44	72.0** ±0.50	-0.33 ±0.47	5.17** ±1.01	6.00** ±0.94	-0.52 ±0.20	-5.00* ±2.02	D
Plant height (cm)	KL 178 x Hira	140.33** ± 0.88	0.33 ±0.66	-1.50 ±3.80	-1.99* ±3.77	-0.50 ±0.74	-7.66** ±4.52	C
	Nagarkot x Neela	139.00** ±0.57	-0.67 ±0.67	6.50** ±2.14	6.67* ±2.67	-1.17 ±0.71	-21.00** ±3.74	D
	Nagarkot x J-23	140.67** ±0.33	0.00 ±0.47	-2.50* ±1.71	-1.33 ±1.63	-0.83 ±0.60	-12.33** ±2.52	C
	RL 993 x Janki	142.67** ±0.33	-1.33 ±0.47	-7.00** ±1.68	-6.67** ±1.63	-1.67 ±0.53	-6.00** ±2.45	C

Table 1 Contd...

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	RL 993 x JRF 5	139.33** ±0.33	0.00 ±0.94	5.17** ±3.08	5.33** ±3.06	-0.58 ±0.78	-21.00** ±4.08	D
	Neelum x Ayogi	140.67** ±0.33	0.33 ±0.88	117.00** ±2.25	- -	- -	- -	-
	Chambal x Ayogi	139.33** ±0.33	0.33 ±0.75	20.33** ±2.14	26.00** ±1.49	1.67 ±1.67	-43.43** ±4.28	D
	Chambal x ES-44	139.67** ±1.45	-0.33 ±0.61	0.83 ±0.61	2.00* ±5.96	-0.83 ±0.96	-13.67** ±6.57	D
Number of primary branches/plant	KL 178 x Hira	73.00** ±0.58	3.33** ±1.34	14.83** ±4.62	14.67** ±4.52	3.17** ±1.97	-20.33* ±8.33	D
	Nagarkot x Neela	74.33** ±0.67	-0.33 ±1.66	17.33** ±4.39	15.33** ±4.27	-6.67 ±1.75	-25.33** ±7.47	D
	Nagarkot x J-23	65.67** ±1.20	-4.67** ±1.05	34.50** ±5.38	22.67** ±5.25	-0.83 ±0.15	-41.00** ±6.82	D
	RL 993 x Janki	80.00** ±2.00	-1.33 ±2.56	32.67** ±10.97	28.00** ±9.50	-2.33 ±5.87	-89.33** ±17.02	D
	RL 993 x JRF 5	74.33** ±2.33	3.00** ±2.21	36.33** ±10.60	31.33** ±10.33	-8.00** ±2.54	-24.67** ±13.90	D
	Neelum x Ayogi	87.33** ±3.48	-19.67** ±2.67	59.17** ±25.26	- -	- -	- -	-
	Chambal x Ayogi	90.00** ±4.04	-24.33** ±2.60	-8.00** ±17.66	- -	- -	- -	-
	Chambal x ES-44	73.00** ±1.53	0.00 ±0.41	26.67** ±10.33	25.33* ±10.24	7.67** ±4.17	-40.00** ±17.75	D
Number of capsules/plant	KL 178 x Hira	6.67** ±0.33	0.00 ±8.17	2.33* ±2.22	1.33 ±2.10	0.00 ±0.91	-7.33** ±3.80	D
	Nagarkot x Neela	6.67** ±0.88	-2.67** ±0.94	6.17** ±4.06	5.33** ±4.00	-3.17** ±0.07	-16.33** ±5.33	D
	Nagarkot x J-23	7.00** ±0.58	0.67* ±0.47	3.67** ±2.52	4.00** ±2.49	0.33 ±0.50	-14.00** ±3.07	D
	RL 993 x Janki	7.00*** ±0.00	2.33** ±0.67	3.33** ±1.53	3.33** ±1.33	2.00* ±0.82	-16.67** ±3.06	D
	RL 993 x JRF 5	7.00** ±1.00	3.00** ±0.58	10.17** ±4.18	10.00** ±4.16	-2.83** ±0.62	-21.16** ±4.69	D
	Neelum x Ayogi	8.00** ±0.57	-1.00 ±0.47	1.83 ±2.65	0.67 ±2.49	-0.83 ±0.50	-10.33** ±3.48	D
	Chambal x Ayogi	8.33** ±0.88	-3.67** ±0.33	-0.33 ±0.36	-0.67 ±3.59	-3.33** ±0.37	-10.00** ±3.84	C
	Chambal x ES-44	7.33** ±0.33	-1.67 ±0.66	2.50** ±1.95	3.33** ±1.89	-1.17 ±0.73	-13.00** ±3.14	D
Days to maturity	KL 178 x Hira	151.67** ± 3.91	-2.00* ±3.78	-36.50** ±17.55	-42.67** ±17.44	-6.50** ±3.59	-81.67** ±22.16	C
	Nagarkot x Neela	143.00** ±6.66	32.33** ±3.14	107.00** ±27.45	122.00** ±27.37	-29.33** ±3.72	-311.09** ±29.78	D
	Nagarkot x J-23	132.67** ±3.76	-11.33** ±3.02	322.67** ±16.40	300.00** ±16.19	-9.33** ±3.40	-580.00** ±19.97	D
	RL 993 x Janki	176.00** ±2.65	-11.00** ±2.21	28.00** ±12.59	19.33** ±11.47	-12.67** ±3.10	273.00 ±17.25	D
	RL 993 x JRF 5	151.33** ±4.18	-18.67** ±3.59	218.17** ±18.42	218.67** ±18.18	-15.50** ±3.96	-468.33** ±22.79	D

Table 1 Contd...

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Neelum x Ayogi	126.33** ±2.73	36.33** ±4.63	225.33** ±15.07	202.00** ±14.31	40.67** ±5.21	-441.33** ±25.50	D
	Chambal x Ayogi	200.33** ±4.84	-69.00** ±5.37	95.17** ±22.60	-110.00** ±22.15	-56.50** ±5.73	-19.00 ±30.30	C
	Chambal x ES-44	159.67** ±3.84	-58.33** ±1.45	100.50** ±15.72	118.00** ±15.64	-32.83** ±1.98	-206.33** ±16.71	D
1000-seed weight (g)	KL 178 x Hira	118.33** ± 1.67	7.67* ±7.77	-70.83** ±17.03	-68.67** ±16.92	28.50** ±7.82	-203.66** ±32.04	C
	Nagarkot x Neela	93.22** ±1.67	-28.33** ±4.71	-43.33** ±11.78	-43.33** ±11.55	-30.00** ±5.00	-193.00** ±20.50	C
	Nagarkot x J-23	129.33** ±2.96	*71.67** ±3.33	-17.33** ±13.80	-20.67** ±13.59	-73.33** ±3.73	-356.00** ±18.45	C
	RL 993 x Janki	150.00** ±2.89	-15.00** ±5.52	-57.33* ±16.85	-43.33** ±15.99	-76.67** ±5.81	-345.33** ±27.11	C
	RL 993 x JRF 5	125.00** ±2.89	-5.00** ±4.08	-35.83** ±14.29	-30.00** ±14.14	-12.50** ±4.25	-315.00** ±20.41	C
	Neelum x Ayogi	101.67** ±4.41	1.67 ±4.40	-83.00** ±19.80	-70.00** ±19.72	-9.67** ±4.47	-147.33** ±25.21	C
	Chambal x Ayogi	116.67** ±3.33	35.00** ±4.08	-113.33** ±15.81	-116.67** ±15.63	28.33** ±4.41	-133.33** ±21.60	C
	Chambal x ES-44	120.00** ±2.89	-46.67** ±4.40	-96.67** ±14.93	-73.33** ±14.52	-33.33** ±5.33	-183.33** ±22.17	C
Seed yield/plant (g)	KL 178 x Hira	7.81** ±0.12	0.37 ±0.26	5.91** ±0.73	5.99** ±0.70	1.23** ±0.27	-12.92** ±1.22	D
	Nagarkot x Neela	7.44** ±0.33	-2.38* ±0.19	1.81 ±1.29	1.41 ±1.27	-2.62** ±0.27	-8.07*9* ±1.50	D
	Nagarkot x J-23	8.45** ±0.25	-0.66** ±0.23	1.81 ±1.11	1.27** ±1.09	-0.82** ±0.25	7.10** ±1.43	D
	RL 993 x Janki	9.46** ±0.25	0.13 ±0.33	-4.07** ±1.20	-3.25** ±1.19	0.61* ±0.35	-3.77** ±1.68	C
	RL 993 x JRF 5	8.94** ±0.13	-1.17** ±0.30	-3.89** ±0.84	-4.20** ±0.79	-1.06** ±0.34	1.81** ±1.43	C
	Neelum x Ayogi	6.99** ±0.27	2.07** ±0.50	5.97** ±1.51	8.40** ±1.47	4.00** ±0.56	-17.21** ±2.46	D
	Chambal x Ayogi	7.62** ±0.7	1.09** ±0.17	3.08** ±0.47	2.15* ±0.45	-0.67** ±0.20	-8.93** ±0.29	D
	Chambal x ES-44	8.27** ±0.17	-0.80 ±0.13	1.07 ±0.74	0.51 ±0.71	-1.34** ±0.19	-5.63** ±0.94	D

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

Table 2 Estimates over superior parent heterosis and inbreeding depression for 10 characters in linseed

Cross	Days to 50% flowering		Plant height (cm)		No. of primary branches/plant		No. of capsules/plant		Days to maturity	
	h(SP)	IB	h(SP)	IB	h(SP)	IB	h(SP)	IB	h(SP)	IB
KL 178 x Hira	6.00**	-4.00**	1.33**	-2.67**	0.33	2.33**	1.00**	-0.67	10.67**	-38.67**
Nagarkot x Neela	1.00**	0.67*	-0.67	-2.00**	8.33**	2.33*	1.33*	-1.00	-18.00**	-24.33**
Nagarkot x J-23	-1.33**	-0.67*	-2.00**	-4.33**	15.67**	7.00**	0.67*	-1.67*	24.67**	16.33**
RL 993 x Janki	3.00	4.67**	0.00	-5.00**	5.67	-6.00**	0.33	-1.00	10.33*	-45.33**
RL 993 x JRF 5	0.33	-1.33**	-0.67	-2.67**	16.00**	12.00**	0.33	-0.33	3.67	8.00*
Neelum x Ayogi	-1.33**	-2.67**	1.00*	0.00	31.33**	17.00**	1.33**	-1.67	27.67**	2.33
Chambal x Ayogi	-7.67**	-0.67*	1.33**	-2.33**	-45.33**	-3.67	0.67*	-2.67	27.33**	-52.33**
Chambal x ES-44	-1.00*	1.33**	-1.67	-3.00*	-9.00**	3.33	-1.33**	-2.00**	43.00**	1.33

Cross	1000-seed weight (g)		Seed yield/plant		Oil content (%)		Iodine value		*Alternaria* blight	
	h(SP)	IB	h(SP)	IB	h(SP)	IB	h(SP)	IB	h(SP)	IB
KL 178 x Hira	-3.00*	-86.33**	0.95*	-0.27	1.41**	0.90	0.95	0.74	-6.00**	-2.33**
Nagarkot x Neela	4.67	-70.00**	0.63*	-1.12**	0.75**	0.26	0.36**	0.06	-1.00	-0.67
Nagarkot x J-23	5.00*	-97.67**	0.73*	-0.87**	-0.42**	0.27	1.39**	0.19	-3.00	-0.67
RL 993 x Janki	-21.33**	-115.00**	-1.29**	1.09**	-0.40	0.11	-0.17	-0.10	2.00	1.33
RL 993 x JRF 5	-13.33**	-96.67**	0.43	-1.49**	0.54**	0.60**	0.73*	0.50	1.00	3.67**
Neelum x Ayogi	-24.33**	-78.33**	4.46**	-1.32**	1.00**	0.57**	0.56*	0.39	-21.00**	4.33**
Chambal x Ayogi	10.00**	-90.00**	2.6**	-0.69**	-0.93**	0.32	0.86*	-0.05	-27.00**	4.00**
Chambal x ES-44	-31.67**	-91.67**	1.11**	-0.87**	-0.86	0.10	-0.53	0.55	20.67**	11.00**

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

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Stability behaviour of some linseed, *Linum usitatissimum* (L.) genotypes under environmental variability

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Abstract

Stability parameters along with per plant performance of 26 promising genotypes of linseed were worked out for 9 yield traits under three different environmental conditions. High significant differences among genotypes were observed for all the characters except days to maturity, number of primary branches/ plant. The significant genotype x environment for all the characters were recorded except for number of secondary branches/plant and number of seeds/capsule. Environment (linear) interaction component was significant for all the traits except number of secondary branches/plant and number of seeds/capsule, while the linear component of environment interaction was significant for all the traits except number of secondary branches/ plant and number of seeds/capsule. The variance due to pooled deviation (non linear) was highly significant for all the characters which reflect considerable genetic diversity in the material. The genotype, R-2548 was stable for number of capsules/plant and seed yield/plant. The genotype, R-2560 was stable for number of secondary branches/plant and seed yield/plant.

Key words: Stability, yield components, linseed

Introduction

In any breeding programme it is necessary to screen and identify phenotypically stable genotypes for yield, which could perform more or less uniformly under different environmental conditions. It is an established fact that yield is a complex character and largely depends upon its component characters, with an interaction with the environment resulting into the ultimate product, i.e., yield. So far breeding a stable variety, it is necessary to get the information on the extent of genotypes x environment interaction (GEI) for yield and its component characters.

Linseed (*Linum usitatissimum* L.) is one of the oldest crop cultivated by man for its seed and fibre. Linseed genotypes express variation under different environments, particularly with yield and yield attributing characters. So in the present study 26 linseed genotypes were evaluated at three diverse environments to analyse the extent of GEI and to find out the stability of these varieties in respect of yield and its components.

Materials and methods

The experimental materials comprised of 26 linseed genotypes in which 20 genotypes were advance lines derived from diverse parents along with six popular varieties. These were evaluated at three different environments viz., rainfed, irrigated and late sown conditions during *rabi*, 2002-03. The experimental materials were sown in Randomized Complete Block Design with 3 replications. Each entry was sown in 4 lines of 4m length, spaced 30 cm row to row and 5-10 cm plant to plant. Recommended agronomic practices were followed to obtain a good crop. Observations were recorded on 10 randomly selected plants from each genotype/replicate on days for flowering, maturity, plant height, number of primary branches/plant, number of secondary branches/plant, number of capsules/plant, number of seeds/capsule, 1000-seed weight and seed yield/plant. The mean data were subjected to stability analysis as per the model of Eberhert and Russell (1966).

Results and discussion

The analysis of variance for individual as well as pooled environments showed that the mean sum of squares due to genotypes were significant for all the characters except days to maturity, number of primary branches/plant (Table 1). The analysis indicated that genotypes interacted strongly with the environment.

Environment (linear) interaction component was significant for all the traits except number of secondary branches/ plant and number of seeds/capsule, while the linear component of environment interaction was significant for all traits except number of secondary branches/plant and number of seeds/capsule. The variance due to pooled deviation (non linear) was highly significant for all the characters which reflect considerable genetic diversity in the material. A variety may be said to be stable over different environments if it shows unity or less than unity regression coefficient (bi) with lowest deviation (non significant) from linear regression (S^2di). The mean x, regression coefficient (bi) and deviation from regression (S^2di) for yield and other related traits are presented in (Table 2).

Table 1 Pooled analysis of variance (*mean square*) for different characters in linseed

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/ plant	No. of secondary branches/ plant	No. of capsules/ plant	No. of seeds/ capsule	1000-seed weight (g)	Seed yield/plant (g)
Genotype	25	80.55**	24.29	46.19**	0.98	5.69**	114.76**	0.97**	2.05**	0.71**
Environment	2	247.72**	40.55**	444.34**	1.53	1.79	1623.01**	0.25	2.73**	0.81**
G x E	50	8.77**	5.79**	6.46	0.55**	1.23	37.24**	0.35	0.11**	0.15**
Environment (linear)	1	495.41**	80.61**	888.67**	3.06**	3.60	3246.01**	0.51	5.47**	16.26**
G x E (linear)	25	8.10**	4.41**	8.75**	0.98**	0.73	63.47**	0.42	0.14**	0.25**
Pooled deviation	26	9.08**	6.92**	4.01**	0.12*	1.66**	10.58**	0.27**	0.072**	0.048**
Pooled error	150	0.73	1.13	5.42	0.22	1.29	15.46	0.35	0.036	0.059

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

Table 2 Estimates of *different stability* parameters for yield and yield components *in linseed*

Genotype	Days to flower			Days to maturity			Plant height (cm)			No. of primary branches/plant			No. secondary branches/plant			No. of capsules/plant		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
R-2530	62.7	0.80	9.18	114.1	3.81*	4.91*	55.9	1.82**	1.31	3.17	-1.07**	-0.07	8.5	2.12	3.48*	31.5	0.25**	4.94
R-2534	57.9	-0.54	34.69**	107.8	1.21	5.80*	51.2	1.26	0.63	3.39	0.95	-0.07	8.7	2.86	3.17*	42.7	1.29	5.57
R-2538	47.1	0.89	8.35**	108.2	1.92	1.64	47.5	1.43	0.94	3.76	-0.90**	-0.07	11.9	1.49	0.21	42.1	0.23**	-4.95
R-2541	55.3	1.21	0.16	107.9	1.16	4.03*	46.7	1.25	1.66	4.12	-3.45**	-0.03	10.1	0.27	0.27	36.3	-0.15**	-3.58
R-2544	52.5	0.93	8.87**	106.6	0.76	0.04	51.9	0.56**	-1.74	3.32	-3.91**	-0.06	9.4	-2.78	2.41	31.9	-0.57**	-2.86
R-2545	46.8	1.33	1.36	104.1	0.50	13.07**	49.8	1.21	5.30	3.64	0.39--	-0.07	9.4	-0.66**	-0.38	32.8	0.81	2.83
R-2546	44.0	1.27	2.15	105.9	1.07	0.52	45.9	0.61	4.09	3.72	-0.37	-0.01	9.9	-1.16	0.10	34.3	0.58	2.81
R-2548	52.9	1.74	8.35**	109.6	2.42	1.15	48.7	1.16	-1.56	4.49	0.33**	-0.07	12.1	-1.47*	-0.38	49.2	1.13*	-4.84
R-2554	51.9	1.04	1.06	105.6	-1.11**	1.40	46.3	0.44	3.32	3.34	-1.34	0.16	10.8	-4.27*	0.25	43.8	0.94*	-5.04
R-2555	51.3	1.60	21.88**	111.9	0.86	21.87**	44.1	0.70	1.66	4.22	0.02	-0.05	11.0	2.08**	-0.43	47.7	1.88*	15.30
R-2556	45.2	0.60	0.98	110.1	1.08	10.86**	47.4	0.48	9.98	3.61	2.66*	0.00	10.7	3.30	0.76	48.7	1.97*	19.04
R-2557	44.1	0.94	1.72	111.3	1.54	19.13**	44.6	0.12	12.68	2.74	-1.09**	-0.05	8.0	0.60	0.69	29.7	0.18**	4.41
R-2558	48.7	2.68	55.26**	106.7	-1.64**	1.80	43.3	1.03	3.26	4.54	2.17**	-0.07	10.4	5.50**	-0.43	40.4	1.61**	0.22
R-2559	43.7	0.79	3.25*	104.2	0.40	9.10**	51.0	0.40**	-1.76	2.91	0.08	0.11	8.6	-1.09	1.55	43.2	0.77	0.93
R-2560	46.8	1.82	10.01**	109.9	1.75	0.72	50.6	1.40	-1.61	3.56	-0.88**	-0.07	10.3	0.84	-0.11	44.2	0.59	2.42
R-2561	50.1	1.94	6.23**	106.1	0.06	17.41**	41.6	0.02**	-0.32	4.13	1.23	-0.07	10.6	0.10	-0.02	45.1	0.91	1.75
R-2562	44.6	0.97	0.25	109.9	0.73	-0.04	54.5	1.43	7.76	3.57	2.67**	-0.07	8.8	5.03	0.95	36.9	1.84*	13.59
R-2565	44.4	0.55*	-0.01	103.5	1.11	6.06*	46.8	0.90	0.31	5.57	11.21**	0.19	8.7	1.74	1.06	35.2	1.76**	1.49
R-2566	44.0	0.94	2.14	105.7	1.54	8.55**	43.7	1.54**	-0.79	3.70	2.37	-0.01	9.6	3.97	0.46	40.7	1.86*	14.32
R-2568	51.9	1.16	0.18	103.7	0.49	0.84	47.1	0.70	4.14	3.76	2.22	1.70**	8.9	-1.16**	-0.27	29.6	0.15**	-4.76
T397	46.8	0.99	3.73*	109.4	3.34*	3.66	46.3	0.99	-1.52	3.40	0.36**	-0.07	6.1	-0.49	5.30*	29.4	0.62	11.46
Neelum	53.8	0.81	4.06*	107.6	1.84	2.78	51.4	1.68	5.01	3.96	1.77	0.01	7.2	-0.16	8.99**	45.0	1.82**	-4.37
LMH62	45.4	0.34	1.69	110.2	1.51	8.33**	38.2	0.80	0.47	4.10	1.58**	-0.07	9.7	2.18	-0.10	39.3	1.66*	8.22
IG8	56.3	-0.04	25.11**	103.8	0.06	16.38**	45.6	0.95	-1.76	3.36	0.20	0.03	9.6	0.38	-0.27	37.1	1.37	42.39
Kiran	52.5	1.03	-0.20	104.5	-0.36**	-0.13	45.6	1.93*	4.07	3.50	3.97**	-0.07	8.4	2.61	4.64*	33.3	1.58	17.41
R552	56.5	0.19	19.06**	107.9	0.06	10.31**	47.8	1.10	1.91	3.48	4.82**	0.00	8.1	3.14	0.12	34.1	0.92	2.24
Mean	49.1	1.00		107.5	1.00		47.4	1.00		3.73	1.00		9.4	1.00		38.7	1.00	
SEm±	2.13	0.69		1.8	1.49		1.4	0.34		0.24	0.99		0.9	3.46		2.3	0.29	

Table 2 (Contd...)

Genotype	No. of seeds/capsule			1000-seed weight (g)			Seed yield/plant (g)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
R-2530	7.96	-6.86**	0.02	6.39	1.51**	-0.01	1.23	0.69*	0.001
R-2534	8.18	2.59	1.76*	6.18	0.74	0.04	2.23	1.54**	0.001
R-2538	7.76	-4.21**	-0.07	6.65	0.84*	-0.01	2.16	0.61*	0.001
R-2541	8.64	-1.73**	-0.10	6.02	1.06	0.001	1.85	0.19*	0.03
R-2544	8.52	-6.96**	-0.07	6.37	0.85	0.04	2.01	0.03**	-0.02
R-2545	7.39	1.73	-0.06	6.57	0.08	0.19	1.59	0.36**	-0.02
R-2546	6.34	7.08**	-0.01	6.72	0.40**	-0.01	1.52	0.30*	0.03
R-2548	6.92	3.81**	-0.11	7.01	1.43	0.02	1.99	0.61	0.03
R-2554	7.06	-1.48	0.19	7.20	1.75	-0.01	3.42	2.50*	0.11
R-2555	7.91	-3.49	-0.01	6.45	1.08	-0.01	2.28	1.68*	0.05
R-2556	7.57	3.07	0.02	6.42	1.03	0.02	2.36	1.37	0.21*
R-2557	7.97	-1.65	-0.07	7.73	1.90*	0.03	1.48	0.07*	0.13
R-2558	7.06	2.63	1.69*	6.27	0.57	0.01	1.76	0.96	-0.01
R-2559	6.93	1.54	-0.10	5.60	-0.13**	-0.01	1.93	0.29**	-0.02
R-2560	8.29	1.72	-0.10	5.78	1.09	-0.01	2.29	1.23	0.01
R-2561	7.13	7.03*	0.04	7.05	1.35	0.07	2.58	1.53*	0.01
R-2562	7.31	9.71**	-0.06	6.56	0.85	0.02	2.04	1.54*	0.02
R-2565	7.29	0.19	0.12	7.05	4.05*	0.28	1 90	1.38**	-0.02
R-2566	7.48	9.40*	0.15	7.00	0.67	0.30	2.21	1.61*	0.02
R-2568	7.49	-1.15	0.51	5.10	0.82*	-0.01	1.33	0.43**	-0.01
T397	6.97	3.84	0.54	7.98	1.51	0.11	1.52	0.56	0.03
Neelum	8.00	7.48**	-0.07	6.40	0.50	0.07	2.50	1.84**	0.06
LMH62	7.99	3-.89**	-0.12	6.63	1.52	0.20	1.71	1.14**	-0.02
IG9	7.24	0.25*	-0.11	5.58	0.30*	0.01	1.54	1.08	0.08
Kiran	8.34	-0.40	-0.07	4.66	0.20	0.23	1.34	1.25	0.05
R552	7.74	-4.26	0.15	4.49	0.01**	-0.01	1.45	1.23**	-0.02
Mean	7.59	1.00		6.38	1.00		1.93	1.00	
SEm±	0.37	3.72		0.19	0.59		0.15	0.28	

bi**, * = Regression coefficient significantly different from unity at P=0.01 and P=0.05, respectively.

S^2di**,* = Deviation from regression significantly different from zero at P=0.01 and P=0.05, respectively

In the present investigation the magnitude of regression coefficient (bi) and deviation from regression varied from genotype to genotype. The first group consisting the genotypes which have high mean value, bi is equals to unity and S^2di is nearly zero were considered as stable genotypes over all the environments studied.

The genotypes, R-2530, R-2554, R-2568 and Kiran were stable for days to flowering. R-2562 was stable for days to maturity. R552 was stable for plant height. Kiran was stable for number of primary branches/plant. R-2560 was stable for number of secondary branches/plant. R-2548, R-2554, R-2559 and R-2561 were stable for number of capsules/plant. R-2555, R-2556 and R-2562 were stable for 1000-seed weight. R-2548 and R-2560 were stable for seed yield/plant.

The genotype, R-2548 was stable for number of capsules/plant and seed yield/plant. R-2554 was stable for days to flowering and number of capsules/plant. R-2560 was stable for number of secondary branches/plant and seed yield/plant. R-2562 was stable for days to maturity and 1000-seed weight. Kiran was stable for two characters i.e., days to flowering, number of primary branches/plant.

The genotypes which are showing high mean value than over all mean but exhibiting above average stability with bi>1 comes under the second group, indicated that they were highly sensitive to environmental conditions. The genotypes performed well under favorable environmental conditions.

The third groups consisting the genotypes, which are showing high mean value than the population mean and exhibiting below average in stability with bi<1, indicating that these genotypes were least sensitive to environmental conditions. It revealed that the genotypes specifically adapted to poor environmental conditions.

These findings were in accordance with the findings of Rai *et al.*, (1989), Mishra and Rai (1993), Mahto (1995), Solanki and Gupta (2000), Bhateria *et al.*, (2001), Patel *et al.*, (2001), Senapati and Sarkar (2002), Adugna and Lauschagne (2002) and Kumari *et al.*, (2003). It can be concluded from the present investigation that the superior lines of linseed i.e., R-2845 and R-2860 would be effectively utilized in breeding programme to improve seed yield of linseed.

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Combining ability for seed yield and its attributes in linseed, *Linum usitatissimum* L.

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Abstract

Six well adapted lines and three diverse testers in linseed (*Linum usitatissimum* L.) were crossed in line x tester fashion to know the desirable parents and crosses for their use in breeding programmes. The analysis of variance for combining ability revealed highly significant differences of the line x tester component for all the characters. Partitioning of combining ability variances into fixable additive genetic variance and non-fixable dominance variance indicated both additive and dominance gene actions play a significant role in controlling the expression of all the traits. The estimates of *gca* effects revealed that the genotypes R-552 among the lines and Polf.22 among the testers were proved as good general combiners for seed yield/plant and could be utilized in future breeding programmes. Significant *sca* effects exhibited by three crosses *viz.*, R-552 x Polf.14, Krian(Y) x SIKO-10 and Ayogi x Polf.14 for seed yield/plant could be used for exploitation of heterosis for yield and its components.

Key words: Line x tester analysis, combining ability, heterosis, linseed

Introduction

Linseed is one of the important *rabi* oilseed crops in India, having very low seed yield as compared to developed countries. So far in India for enhancing linseed yield, the research efforts made have mostly been concentrated towards individual plant selection of land races and progeny selection followed by hybridization of parents having higher per se performance. The present investigation was undertaken to determine the level of heterosis and combining ability for identification of good combiners from high yielding varieties and promising crosses for future breeding accomplishments.

Materials and methods

Six well adapted cultivars/elite lines were crossed as female with three diverse genotypes as pollinators in a line x tester design (Kempthorne, 1957). The crosses were made in line x tester design during *rabi*, 2003-2004. Eighteen F_1s along with nine parents were grown in Randomized Complete Block Design with three replications at the Research Farm of Indira Gandhi Agricultural University, Raipur during *rabi*, 2003-04. Each treatment in a replication had single row of 4 m length at 30 x 10 cm spacing between and with in the row, respectively. All the recommended cultural practices were followed. Data were recorded on five randomly selected competitive plants from each genotype per replication for various traits given in tables. The analysis of variance was worked out as per standard procedure whereas combining ability analysis as per Kempthorne (1957).

Results and discussion

The analysis of variance for combining ability revealed highly significant differences of the line x tester component for all the characters, indicating that the material chosen was desirable. The lines showed significant differences for days to flower, number of secondary branches/plant, 1000-seed weight and number of seeds/plant. While the testers exhibited significant differences for days to flower and 1000-seed weight (Table 1).

Partitioning of combining ability variances into fixable additive genetic variance and non-fixable dominance variance indicated both additive and dominance gene actions play a significant role in controlling the expression of all the traits. Therefore, it would be beneficial to buildup a population by inter-mating these parents inter se before initiating random mating in F_2 to allow higher recombination. There was preponderance of dominance gene action for days to maturity, plant height, number of primary branches/plant, number of secondary branches/plant, number of capsules/plant, seed yield/plant, number of seeds/plant and harvest index. The results are in agreement with Thakur and Rana (1987) and Mahto and Rahman (1998) for predominance of additive gene action was recorded for days to flower, number of seeds/capsule and 1000-seed weight. When additive effects form the principal factor for genetic variance, use of pedigree method could be desirable.

The estimates of *gca* effects revealed that the line R-552 and Polf.22 as tester were proved as good general combiners for seed yield/plant (Table 2). Parents R-552 and Polf.22 were also found good general combiners for early flowering, number of primary branches/plant, numbers of secondary branches/plant, number of seeds/plant. In addition to these Polf.22 was also good

combiner for earlier maturity. Kiran was found to be good combiner for early flowering and number of seeds/plant. The *gca* for other characters revealed that parents LCK-88062 for plant height, number of primary branches/plant, number of secondary branches/plant, number of capsules/plant, number of seeds/capsule and 1000-seed weight; Kiran(Y) for days to maturity, number of capsules/plant and harvest index; Solan for plant height; *Ayogi for days to maturity, number of* seeds/capsules and 1000-seed weight; Polf.14 for number of seeds/capsule; SIKO-10 for days to flower and number of capsules/plant were the best general combiners. Crosses involving these parents might produce heterotic hybrids with high mean performance for respective traits.

High *sca* effects mostly from the dominance and interaction effects existed between the hybridizing parents. In the present study, significant *sca* effects were exhibited by three crosses viz. R-552 x Polf.14, Krian (Y) x SIKO-10 and Ayogi x Polf.14 for seed yield/ plant (Table 3 and 4). All the three crosses having significant *sca* effects, recorded higher per se performance, where both of the parents involved in the combination having low *gca* effect. In addition to seed yield/ plant, crosses with significant and positive *sca* effect for different traits were R-552 x Polf.14 for late maturity, tallness, number of primary branches/plant, number of secondary branches/plant, number of capsules/plant and number of seeds/plant; Kiran(Y) x SIKO-10 for late maturity, tallness, number of secondary branches/plant, number of capsules/plant and number of seeds/plant and Ayogi x Polf.14 for early maturity, dwarfness, number of secondary branches/plant, number of capsules/plant, number of seeds/plant and harvest index. Thus all these crosses were found to be outstanding with respect to seed yield and its component traits. These findings favour the *establishment of a hybridization programme and the* development of suitable male sterile lines (Dubey and Singh, 1966). These crosses also showed significant heterobeltiosis for seed yield and its contributing characters (Table 5). It was observed that crosses involving one low and the other high or low general combining parent would produce heterotic hybrids. Earlier workers like Dakhore *et al.*, (1987), Singh *et al.*, (1987), Pillai *et al.*, (1995), Kumar *et al.*, (2000), Bhateria *et al.*, (2001), Kumar *et al.*, (2002) and Kusalkar *et al.*, (2002) also reported similar results for grain yield and yield attributing traits in linseed using different genotypes.

From this study it was noted that both additive and non additive gene effects were important in controlling various characters. The best combiners R-552 and Polf.22 could be utilized in future breeding programmes. The crosses R-552 x Polf.14, Kiran (Y) x SIKO-10 and Ayogi x Polf.14 could be used for exploitation of heterosis for yield and its components.

Table 1 Analysis of variance of combining ability for different characters in linseed

Source	D.F.	Days to Flower	Days to maturity	Plant height (cm)	Number of primary branches/ plant	Number of secondary branches/ plant	Number of capsules/ plant	Number of seeds/ capsule	Seed yield/ plant (g)	1000-seed weight (g)	Number of seeds/ plant	Harvest index (%)
Replications	2	74.9	7.4	7.5	2.4	4.7	1092.5	0.1	0.7	0.2	17500.7	16.9
Lines	5	116.7*	75.9	245.1	2.9	105.4*	1939.8	3.0	2.2	4.1**	39427.8*	69.0
Testers	2	122.5*	40.2	465.5	2.1	42.2	1324.1	3.1	2.4	8.3**	14392.1	9.3
Line x Tester	10	2.0**	133.2**	131.7**	1.2*	32.0**	862.8**	1.2*	1.0**	0.6**	13973.9**	47.9**
Error	34	4.0	2.27	13.5	0.4	6.4	46.9	0.5	0.2	0.2	4337.7	13.2
Additive genetic variance	σ2 A	15.5	-11.1	33.1	0.2	6.2	113.9	0.3	0.2	0.8	1916.4	-1.3
Dominance variance	σ2 D	6.0	43.7	39.4	0.2	8.5	271.9	0.2	0.3	0.1	3212.1	11.6
Degree of dominance	σ2 A/ σ2 D	0.4	-3.9	1.2	1.2	1.4	2.4	0.9	1.4	0.2	1.7	-8.9

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

Table 2 Mean (X) and general combining ability (*gca*) effects for different parents for different traits in linseed

Parent/character	Days to flower		Days tomaturity		Plant height (cm)		No. of primary branches/plant		No. of secondary branches/plant		No. of capsules/ plant	
	X	gca	X	gca	X	gca	X	gca	X	gca	X	gca
Lines												
Kiran	65.6	-5.6**	103.6	1.0**	56.4	-0.2	3.5	0.0	12.2	0.6	47.1	0.4
R-552	57.3	-2.4**	105.0	0.8*	57.6	-1.2	3.6	0.7**	11.1	2.1**	43.6	20.0**
LCK-88062	63.3	2.4**	107.0	3.7**	71.0	8.4**	3.5	0.5**	11.2	4.2**	37.3	8.6**
Kiran(Y)	62.0	-0.6	118.6	-4.7**	50.8	-2.9**	3.0	-0.0	10.1	1.0	36.4	4.7**
Solan	65.0	2.1**	118.6	0.9*	64.1	2.8**	2.9	-0.4**	10.0	-3.1**	30.2	-15.4**
Ayogi	77.3	4.2**	121.0	-1.8**	92.7	-6.8**	3.0	-0.7**	7.6	-4.9**	25.8	-18.4**
SE(gi)		0.5		0.3		0.9		0.1		0.6		1.7
Testers												
Polf.14	69.0	2.8**	118.3	0.9**	69.9	5.5**	3.2	0.1	7.1	-1.0*	19.8	-9.8**
Polf.22	59.3	-2.2**	102.6	-1.7**	51.9	-4.5**	4.7	0.2*	13.3	1.7**	48.4	6.1**
SIKO-10	63.6	-0.6*	117.6	0.7**	61.6	-0.9	3.8	-0.3**	13.2	-0.7	49.2	3.6**
SE (gi)		0.3		0.2		0.5		0.1		0.4		1.0

Parent/character	No. of seeds/ capsule		Seed yield/plant (g)		1000-seed weight (g)		No. of seeds/plant		Harvest index (%)	
	X	*gca*	X	*gca*	X	*gca*	X	*gca*	X	*gca*
Lines										
Kiran	7.7	-0.1	1.6	0.2	5.7	-0.3**	279.3	54.7**	27.6	0.5
R-552	6.8	-0.8**	1.4	0.8**	6.6	0.2*	214.6	91.2**	24.7	1.2
LCK-88062	8.0	0.4**	1.4	-0.0	7.0	0.3**	199.3	-21.3	22.3	-5.4**
Kiran(Y)	6.8	0.2	0.9	-0.0	6.1	0.01	147.4	-9.0	21.2	2.4*
Solan	7.7	-0.3*	0.8	-0.5**	3.6	-1.1**	224.4	-16.8	13.5	0.2
Ayogi	7.9	0.6**	0.4	-0.4**	3.4	0.8**	110.3	-98.7**	7.9	1.0
SE(gi)		0.1		0.1		0.1		16.3		0.9
Testers										
Polf.14	7.2	0.4**	0.3	-0.3**	3.1	-0.6**	95.6	-22.1*	6.0	-0.4
Polf.22	6.4	-0.2*	1.4	0.4**	5.6	0.6**	219.3	31.8**	27.3	-0.3
SIKO-10	7.5	-0.2	1.5	-0.1	4.6	0.01	330.3	-9.7	28.7	0.8
SE (gi)		0.1		0.1		0.07		10.3		0.5

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

Table 3 Estimates of specific combining ability (*sca*) effects of crosses for different traits in linseed

Source	Days to Flower	Days to maturity	Plant height (cm)	Number of primary *branches/plant*	Number of secondary *branches/ plant*	Number of capsules/ plant	Number of seeds/ capsule	Seed yield/ plant (g)	1000-seed weight (g)	Number of seeds/ plant	Harvest index (%)
Kiran X Polf.14	3.00**	-2.72**	5.66**	0.62**	1.23	-5.74*	0.22	0.01	-011	13.21	-0.84
Kiran X Polf.22	-1.56*	7.61**	-3.37*	-0.04	-1.41	-2.08	0.31	0.13	-0.16	24.47	-2.14
Kiran X SIKO-10	-1.44*	-4.89**	-2.29	-0.59*	0.18	7.81**	-0.53*	-0.14	0.27	-37.68	2.98*
R-552 X Polf.14	*3.78***	*3.63***	*7.99***	*0.73***	*2.29**	*24.34***	*-0.66***	*0.68***	*0.23*	*63.30***	*-4.09**
R-552 X Polf.22	-3.78**	-3.17**	-0.91	-0.39	-1.41	-9.67**	0.37	0.20	0.15	24.33	3.31*
R-552 X SIKO-10	0.001	-0.67	-7.09**	-0.34	-0.89	-14.67**	0.29	-0.88**	-0.38*	-87.33**	0.78
LCK-88062X Polf.14	-0.33	3.94**	2.93*	-0.54*	-2.40*	-2.89	0.11	-0.19	-0.03	-10.49	-4.09*
LCK-88062X X Polf.22	1.78*	-1.39*	2.36	0.21	5.50**	16.10**	-1.10**	-0.13	0.05	-26.66	-1.73
LCK-88062X X SIKO-10	-1.44*	-2.56**	-5.29**	0.33	-3.11**	-13.21**	0.99**	0.32	-0.03	37.15	5.82**
Kiran(Y) X Polf.14	*-2.67***	*-4.94***	*-7.21***	*-0.90***	*-4.11***	*-19.00***	*-0.01*	*-0.82***	*-0.10*	*-113.04***	*1.52*
Kiran(Y) X Polf.22	1.78*	3.39**	-1.51	0.64**	0.66	3.25	0.54*	0.16	-0.19	39.32	0.61
Kiran(Y) X SIKO-10	0.89	1.56**	8.71**	0.26	3.45**	15.75**	-0.53*	0.66**	0.29	73.73**	-2.13
Solan X Polf.14	-1.67*	6.72**	-1.23	-0.36	0.23	-13.22**	0.09	-0.33	-0.63**	-24.92	4.04*
Solan X Polf.22	-0.22	-1.94**	0.001	0.05	0.13	8.83**	-0.06	0.18	0.67**	-4.76	0.10
Solan X SIKO-10	1.89*	-4.78**	1.23	0.30	-0.35	4.39	-0.03	0.15	-0.05	29.68	-4.14*
Ayogi X Polf.14	*-2.11***	*-6.93***	*-8.14***	*0.44*	*2.76***	*16.51***	*0.24*	*0.65***	*0.63***	*71.94***	*3.47**
Ayogi X Polf.22	2.00	-4.50**	3.43*	-0.48*	-3.47**	-16.44	-0.07	-0.54**	-0.53**	-56.69*	-0.15
Ayogi X SIKO-10	0.11**	11.33**	4.71**	0.04	0.71	-0.07	-0.18	-0.11	-0.11	-15.25	-3.32*
SE±	0.70	0.52	1.29	0.23	0.89	2.41	0.24	0.17	0.15	23.14	1.28

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

Table 4 Promising hybrid combinations with significant specific combining ability effects in linseed

Name of the Character	Promising hybrids
Days to flower	R-552 X Polf.22, Kiran (Y) X Polf.14, Ayogi X Polf.14
Days to maturity	Ayogi X Polf.14 Kiran (Y) X Polf.14, Kiran X SIKO-10
Plant height (cm)	Ayogi X Polf.14 Kiran (Y) X Polf.14, R-552 X SIKO-10
Number of primary branches/ plant	R-552 X Polf.14, Kiran (Y) X Polf.22, Kiran X Polf.14
Number of secondary branches/plant	LCK-88062 X Polf.22, Kiran (Y) X SIKO-10,Ayogi X Polf.14
Number of capsules/ plant	R-552 X Polf.14, Ayogi X Polf.14, LCK-88062 X Polf.22
Number of seeds/ capsule	LCK-88062 X SIKO-10, Kiran (Y) X Polf.22, R-552 X Polf.22
Seed yield/ plant (g)	R-552 X Polf.14, Kiran (Y) X SIKO-10, Ayogi X Polf.14
1000-seed weight (g)	Solan X Polf.22, Ayogi X Polf.14, Kiran (Y) X SIKO-10
Number of seeds/ plant	Kiran (Y) X SIKO-10, Ayogi X Polf.14, R-552 X Polf.14
Harvest Index (%)	LCK-88062 X SIKO-10, Solan X Polf.14, Ayogi X Polf.14

Table 5 Heterobeltiosis in crosses for seed yield and its components in linseed

Source	Days to Flower	Days to maturity	Plant height (cm)	Number of primary branches/plant	Number of secondary branches/plant	Number of capsules/ plant	Number of seeds/ capsule	Seed yield/ plant (g)	1000-seed weight (g)	Number of seeds/ plant	Harvest index (%)
Kiran X Polf.14	-8.21**	-7.32**	31.05**	38.78*	100.93**	143.29**	6.48	634.07**	63.94**	325.68**	332.23**
Kiran X Polf.22	-18.27**	13.18**	5.78	13.21	17.93	44.30**	9.37	110.78**	15.04*	115.41**	-9.11
Kiran X SIKO-10	-15.74**	-8.78**	5.55	-20.75	10.33	59.83**	-17.26*	50.87*	36.61**	32.01**	12.91
R-552 X Polf.14	-2.42	-1.97*	30.90**	63.27**	136.45**	392.95**	-11.27	1067.03**	91.13**	416.13**	290.20**
R-552 X Polf.22	-7.87*	1.27	8.73	20.37	43.11*	82.90**	-1.56	162.88**	31.37**	137.00	25.02*
R-552 X SIKO-10	-5.76*	-5.38**	-6.48	3.70	25.15	65.73**	-7.35	54.29*	36.03**	65.47**	19.69
LCK-88062X Polf.14	-1.45	0.56	14.30**	18.37	100.93**	198.66**	12.96	482.42**	88.05**	221.32**	179.21**
LCK-88062X Polf.22	2.63	3.74	33.50**	33.96*	121.89**	152.50**	-3.65	82.38**	30.79**	73.21**	-14.04
LCK-88062 X SIKO-10	0.001	-4.53**	5.84	18.8	23.08	67.32**	10.62	80.24**	45.01**	84.35**	25.15*
Kiran(Y) X Polf.14	-9.18**	-14.08**	14.94*	-4.35	30.84	97.99**	14.71	292.31*	75.68**	127.00**	402.42**
Kiran(Y) X Polf.22	0.001	0.63	6.42	50.00**	66.45**	114.58**	18.75*	216.79**	20.80**	187.18**	38.42**
Kiran(Y) X SIKO-10	-1.57	-8.22**	33.55**	16.30	69.08**	142.25**	-2.94	217.88**	45.01**	182.30**	31.26*
Solan X Polf.14	-3.86	0.28	9.56*	4.55	33.64	25.50	0.93	284.62*	23.90*	210.91**	407.98**
Solan X Polf.22	-3.59	-9.27**	18.36**	22.73	22.00	71.01**	-0.52	65.37**	80.66**	69.41**	97.04**
Solan X SIKO-10	2.05	-9.55**	7.46	9.09	-8.00	52.17**	-14.16	131.02	42.88**	62.36**	74.75**
Ayogi X Polf.14	-12.07**	-15.15**	-23.36**	17.78	43.93	159.73**	18.06*	632.97**	125.58**	226.55**	411.73**
Ayogi X Polf.22	-13.36**	-15.43**	6.16	-8.89	-49.00**	33.76	16.15	324.19**	113.51**	115.47**	243.32**
Ayogi X SIKO-10	-13.79**	-0.28	-2.70	-13.33	-35.86*	87.37**	-1.77	309.87**	106.56**	115.32	218.77**
SE±	1.78	1.15	2.96	0.50	1.88	5.78	0.55	0.34	0.32	0.50	2.69

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

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Metabolic changes in developing seeds and pod wall of mustard, *Brassica juncea* (L.) Czern & Coss influenced by *Alternaria brassicae*

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Abstract

***Alternaria* severity on mustard crop increased with advancing age of the plant. Total sugars, reducing sugars and starch were higher in healthy plant parts (seeds and siliqua wall) as compared to infected ones. There was an accumulation of sugar at the onset of *Alternaria* infection followed by decline till maturity. A consistent increase in phenol content was observed with the increase in severity of disease. In the healthy plant parts, oil content increased with the age of the plant whereas significant decrease was noticed due to infection by *Alternaria*. Free fatty acids of infected seeds were found to be high as compared to healthy ones. The level of phospholipids, glycolipids and sterols decreased with age as well as disease severity. Erucic acid (22:1) increased, whereas other unsaturated fatty acids (20:1, 18:3, 18:2) decreased with the progression of infection. Alterations in various biochemical components of infected plant parts signify their role in disease resistance.**

Key words: *Brassica juncea, Alternaria brassicae,* pod wall, sugars, phenols, lipids, fatty acids

Introduction

Oilseed *brassicas* occupy a prominent third place ranking next only to soybean and groundnut as oilseed crops in India. During the year 2004-05, the area, production and productivity of rapeseed-mustard were 6.85 m ha, 8.36 m tonnes and 1220 kg/ha respectively (Anonymous, 2006). *Alternaria* blight, caused by *Alternaria brassicae* (Berk) Sacc. is a major disease of *Brassica* crops, a severe menace in sustaining higher yields. In the epidemic years, *alternaria* infestation may cause 38-46% reduction in yield in most mustard growing states of India (Kolte and Singh, 1997). The information on various metabolic changes occurring in host under diseased conditions is scanty particularly in *B. juncea*. The increase in phenol and sugars, changes in lipid and fatty acid profile in leaves of *B. juncea* infested with *Alternaria* brassicae have been reported (Atwal *et al.*, 2004; 2005). The studies suggested the defensive role of these components against *alternaria*. The present studies were taken up on various compositional changes in seed and pod wall of *B. juncea* at different developmental stages infected with *altemaria* disease.

Materials and methods

Indian mustard (*B. juncea*) var. RLM 1359 was raised following standard package of agronomic practices (Anonymous, 2005). Healthy and infected pods were collected at 60, 70 and 80 days after flowering (DAF) and immediately preserved in ice. The percentage infection and percentage severity on pod wall at different stages of infection was calculated as per the standard method of *Conn et al. (1990). The seeds and siliqua walls were* subsequently separated and stored at -20°C. Analysis of samples for various biochemical parameters was carried out on the day of sampling itself. Weighed quantity of seed, pod wall was taken in pre-weighed glass crucibles and dried in oven at 60°C for 48 h till a constant weight was obtained and was subjected to biochemical analysis.

Total lipids from seeds and siliqua wall were extracted as per Folch *et al.* (1957). The percentage of total lipids was determined by evaporating a suitable aliquot of this extract to a constant weight. Phospholipids (PLs) as per Ames (1966); glycolipids (GLs) as per Roughan and Bhatt (1968); sterols as per Zak (1957) and free fatty acids as per Lowry and Tinsley (1976) were estimated by standard procedures. Triglycerides were calculated as relative percentage by substracting the sum of PL's, GL's, sterols and free fatty acids out of 100.

Results and discussion

The percentage infection and severity increased with the age of the plant. Total reducing sugars were significantly higher in healthy as compared to infested seeds of *B. juncea*, and peaked at 70 days after flowering (DAF). Thereafter the amount declined (Table 1). Yesuraja and Mariappan (1993) also reported accumulation of sugars, initially at the onset of infection which decreased, as the age and infection in plant increased in rice crop. A similar trend was observed in the level of reducing and nonreducing sugars under above mentioned conditions (Table 1).

Table 1 **Sugars and phenol content (mg/g dry weight) in the seeds and siliqua wall of Indian mustard as influenced by *Alternaria* blight**

DAF	Seeds		Siliqua wall	
	Healthy	Infected	Healthy	Infected
Total sugars				
60	121.2±6.7	113.4±5.8	139.2±5.2	116.2±2.0
70	239.4±5.9	202.5±4.4	226.4±3.0	211.3±3.2
80	194.3±3.2	182.3±2.2	203.5±1.9	188.6±2.9
CD (P=0.05)	Sampling = 2.1		= 3.2	
	Infected x healthy = 1.4		= 1.8	
Reducing sugars				
60	28.0±1.1	21.6±1.3	59.2±1.2	36.0±0.9
70	59.2±1.1	44.4±1.0	68.1±1.0	49.4±0.6
80	51.4±1.2	36.5±2.2	64.0±2.1	42.1±1.2
CD (P=0.05)	Sampling = 3.3		= 2.1	
	Infected x healthy = 1.4		= 1.4	
Non-reducing sugars				
60	93.2±5.4	91.8±3.2	80.0±0.9	80.2±6.0
70	180.2±2.2	158.1±2.4	158.3±1.1	161.9±8.1
80	142.9±2.9	145.8±3.1	139.5±3.1	146.5±3.2
CD (P=0.05)	Sampling = 2.31		= 3.9	
	Infected x healthy = 1.12		= 1.9	
Starch				
60	98.1±2.2	86.0±2.1	56.4±2.1	42.0±0.9
70	112.3±3.1	104.3±1.0	81.1±4.9	42.0±0.9
80	104.5±4.1	94.6±1.8	68.3±3.8	63.2±1.1
CD (P=0.05)	Sampling = 2.1		= 2.8	
	Infected x healthy = 1.1		= 1.3	
Total phenols				
60	2.2±0.4	3.6±1.1	1.0±0.3	2.1±0.9
70	4.7±0.6	7.1±0.5	2.0±0.4	3.6±0.3
80	7.1±1.0	7.9±0.3	2.8±0.2	4.3±0.1
CD (P=0.05)	Sampling = 1.2		= 0.2	
	Infected x healthy = 1.0		= 0.0	
Orthodihydroxy phenols				
60	0.7±1.3	2.4±0.5	0.3±0.2	1.1±0.1
70	2.5±0.1	3.2±0.9	1.1±0.0	1.6±0.3
80	2.9±0.2	4.1±1.5	1.4±0.1	2.0±0.3
CD (P=0.05)	Sampling = 1.4		= 0.1	
	Infected x healthy = 0.8		= 0.0	
Flavonols				
60	1.8±1.2	1.1±0.4	0.8±1.1	0.8±0.2
70	4.3±1.1	1.8±0.2	2.2±0.9	1.6±0.4
80	3.5±0.7	1.4±0.2	1.6±1.1	1.1±0.0
CD (P=0.05)	Sampling = 1.9		= 0.2	
	Infected x healthy = 0.9		= 0.0	

DAF = Days after flowering

Starch content in healthy and infested seeds was highest at 70 DAF (Table 1). On the contrary, the level of starch in infested siliqua wall, was maximum at 80 DAF, which might be due to its transportation from leaves to siliqua wall. Starch synthesized at initial stage of plant growth later serves as a transient reserve for the biosynthesis of lipids during seed development (Munshi and Kochar, 1994).

The quantitative differences in the total phenols, orthodihydroxy phenols and flavonols were determined between healthy and infested seeds and siliqua wall of *B. juncea* (Table 1). In general, the level of total and orthodihydroxy phenols was more in alternaria infested seeds as compared to healthy ones suggesting their role in disease resistance. Their accumulation was significantly high at the initial stages of disease onset (70 DAF). However irrespective of healthy or infested seeds, the content of these increased with the age of the plant. These results are in agreement with the observations of Gupta *et al.* (1990), who revealed an increase in total and orthodihydroxy phenol level after onset of infection. In contrast to above observations, the level of flavonols was significantly low in infected seeds as compared to healthy seeds. However, significant increase in the content of flavanols was noticed in both healthy and diseased seeds till 70 DAF.

Increased accumulation of total, orthodihydroxy phenols and flavonols with the progression of infection was also noticed in siliqua wall (Table 1). But the levels of these phenols was significantly lower in pod wall as compared to seeds. However, Chakrabarty *et al.* (2002) reported that cotton cultivars resistant to grey mildew (Ramularia areala) displayed higher levels of total phenols, gossypol and flavanols when infected by the pathogen.

Total oil content was significantly lower in alternaria infested as compared to healthy seeds though there was a significant increase in oil content with the age of the plant in healthy and a decrease in alternaria infested seeds and siliqua were respectively (Table 2).

Shah and Ali (2002) also showed a decrease in the oil content of mustard seeds following infection by *Alternaria*. At the initial stage of infection the content of all the lipid classes (PL, GL, Sterols) was less in infected seed except triglycerides as compared to healthy seeds. The high amount of phospholipids and glycolipids at 60 DAF might be due to their enhanced biosynthesis for membrane formation. A decrease at later stages was relative because the accumulation of triglycerides and other neutral lipids took place during this period (Munshi, 1997). There was a significant increase in the free fatty acid content in the disease infested seeds as compared to healthy seeds. The increase in free fatty acid content has also been shown by Rai and Saxena (1980). The increase in the level of 18:1 and 18:2 fatty acids of alternaria infested seeds of *Brassica* till 70 DAS could be expected to overcome the disturbances in membrane fluidity due to *Alternaria* infestation whereas the decrease in level of (22:1) fatty acid (Table 3) of seeds has also been noticed earlier in leaves of Brassica (Atwal *et al.*, 2005).

It may be concluded that the change in level of sugars and phenols might be a defensive step to restrict the growth of fungus, whereas modulation of lipid profile and unsaturated fatty acids under diseased conditions might guard against penetration of the pathogen in plant tissues, since lipids and fatty acids play a crucial role towards membranes integrity.

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Table 2 **Oil content (%) and lipid composition (g/100g oil) in the seeds and siliqua wall of Indian mustard as influenced by *Alternaria blight***

DAF	Seeds		Siliqua wall	
	Healthy	Infected	Healthy	Infected
Total oil content				
60	25.0±1.2	22.0±1.1	2.0±1.1	1.8±0.0
70	34.0±2.1	20.0±1.0	4.0±0.9	1.0±0.0
80	37.0±2.0	15.0±0.9	5.5±2.4	0.7±0.1
CD (P=0.05)	Sampling = 2.2		= 1.5	
	Infected x healthy = 1.3		= 0.1	
Phospholipids				
60	9.8±0.4	6.2±0.5	6.3±0.8	5.1±0.3
70	5.2±0.2	4.1±0.7	5.1±0.2	4.2±0.7
80	3.7±0.1	3.3±0.3	4.4±0.3	3.6±0.1
CD (P=0.05)	Sampling = 1.9		= 1.3	
	Infected x healthy = 1.1		= 0.2	
Glycolipids				
60	6.4±0.4	6.2±0.3	4.2±0.0	3.9±0.0
70	5.1±0.1	4.8±0.2	3.3±0.1	3.1±0.2
80	4.2±0.3	3.6±0.4	2.7±0.1	2.4±0.1
CD (P=0.05)	Sampling = 1.5		= 1.4	
	Infected x healthy = 1.0		= 0.9	
Sterols				
60	1.9±0.1	1.6±0.0	2.0±0.1	1.9±0.2
70	2.1±0.1	1.9±0.1	2.8±0.1	2.4±0.2
80	1.7±0.1	1.7±0.1	2.6±0.0	2.1±0.2
CD (P=0.05)	Sampling = 1.8		= 1.5	
	Infected x healthy = 0.2		= 0.8	
Free fatty acids				
60	0.9±0.1	1.1±0.1	0.8±0.1	1.1±0.1
70	2.0±0.1	2.6±0.1	1.2±0.1	1.5±0.1
80	2.2±0.1	2.8±0.1	1.9±0.1	2.1±0.0
CD (P=0.05)	Sampling = 0.3		= 1.5	
	Infected x healthy = 0.1		= 1.0	
Triglycerides				
60	81.0±0.1	84.9±1.2	86.7±0.9	88.0±0.2
70	85.6±0.8	86.6±1.3	87.6±0.4	88.8±0.0
80	88.2±1.3	88.6±1.2	88.4±0.5	89.8±0.1
CD (P=0.05)	Sampling = 0.8		= 1.6	
	Infected x healthy = 0.4		= 0.3	

DAF = Days after flowering.

Table 3 Fatty acid composition (%) in the seeds of Indian mustard influenced by *Alternaria* blight

Fatty acids	Days after flowering (DAF)					
	60		70		80	
	Healthy	Infected	Healthy	Infected	Healthy	Infected
16:0	3.9	4.2	5.0	3.8	3.1	2.7
18:0	-	-	0.9	-	-	-
18:1	10.0	12.6	11.7	13.5	11.0	10.7
18:2	17.2	18.0	17.5	18.4	15.7	15.2
18:3	11.4	10.0	9.3	10.3	7.9	9.7
20:1	5.6	7.2	6.5	5.1	7.5	5.0
22:1	51.5	46.5	48.6	47.5	53.6	53.7

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Water use efficiency and its relation to specific leaf area, carbon isotope discrimination and total soluble proteins under mid-season moisture stress conditions in groundnut, *Arachis hypogaea* L. genotypes

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Abstract

Variation in water use efficiency (WUE), total dry matter production, specific leaf area (SLA), carbon isotope discrimination ($\Delta^{13}C$) and total soluble proteins were examined in leaves of fifteen groundnut (*Arachis hypogaea* L.) genotypes grown in field under mid-season moisture stress conditions. WUE among groundnut genotypes varied from 2.10 to 2.93 g/kg under stress condition representing a significant variability. Genotypes Tir 16, Tir 14 and Tir 13, produced high total dry matter production and pod yields/plant under moisture stress, also had higher WUE values. The genotypic variation in $\Delta^{13}C$ was recorded from 18.2 to 20.2 $^{0}/_{00}$ under stress condition. Negative correlation was observed between WUE and $\Delta^{13}C$ ® = -0.87, P<0.05) and between WUE and SLA ® =-0.89, P<0.05). A strong positive relationship was observed between WUE and total soluble proteins ® = 0.62, P< 0.05). The study suggest that, in groundnut, genotypic variation in $\Delta^{13}C$ was mostly (>60%) attributable to total soluble protein in leaves as Rubisco constituted about 37% of the soluble protein in groundnut genotypes.

'ey words: Groundnut, WUE, SLA, carbon isotope discrimination, total soluble proteins

'uction

ecent past physiological traits of groundnut
ı to superior performance under drought
ve been identified and substantial genetic
ved for them. Nageswara Rao *et al.* (1989)
s, rought tolerance for mid-season moisture
stre attempted with moderate yield potential,
as hig ding groundnut genotypes appeared to be more susceptible under mid season drought. Recent studies have identified indirect selection tools, carbon isotope discrimination ($\Delta^{13}C$) in leaf and specific leaf area (SLA), which are associated with water use efficiency in groundnut (Wright *et al.*, 1994). In groundnut genotypic differences in WUE appear to be associated with photosynthetic capacity per unit leaf area rather than stomatal factors (Hubick *et al.*, 1986; Wright *et al.*, 1988). In plant species with the C_3 photosynthetic pathway, variation in $^{13}C/^{12}C$ can be a useful indicator of WUE. A strong correlation between $\Delta^{13}C$ and WUE has been shown in field grown crops (Nageswara Rao *et al.*, 1993). Low $\Delta^{13}C$ and high WUE were shown to be associated with the leaf thickness in groundnut, suggesting that an easily measurable parameter like SLA could be effectively used as a surrogate for $\Delta^{13}C$ to assess WUE (Nageswara Rao and Wright, 1994). The CO_2 assimilation rate has been shown to be directly proportional to the amount of photosynthetic enzyme, i.e., ribulose 1,5-bisphosphate carboxylase-oxygenase (Rubisco), present in leaves (Von Caemmerer and Farquhar, 1981). Rubisco constituted about 37% of the soluble protein in groundnut genotypes (Nageswara Rao *et al.*, 1995).

Keeping this in view, the present study was conducted to examine the genotypic variation in WUE and its relationship with total dry matter, SLA, $\Delta^{13}C$ and total soluble proteins in 15 groundnut genotypes under mid-season moisture stress conditions.

Materials and methods

Fifteen groundnut (*Arachis hypogaea* L.) genotypes were grown in the field under mid-season moisture stress conditions during the *kharif* season of 2001 at S.V. Agricultural College, Tirupati, Andhra Pradesh in a randomized block design replicated thrice. Drought conditions were created using rain out shelters (ROS) during 40-80 days after sowing (mid-season moisture stress). Irrigation was withheld between 40-80 DAS and the crop was protected from rain utilizing rain out shelters. During the normal drought stress free period (0 to 40 DAS and 80 DAS to harvest) the crop received regular irrigations based on cumulative pan evaporation (Replenishing 80% pan evaporation after taking the rainfall if any, into account).

Plants were uprooted and plant parts i.e., shoot (leaves and stem) and reproductive structures (pegs and pods) after separation were dried in an oven at 80°C to record dry weight. Fully expanded leaf from the top on the primary branch were collected, cleaned and their leaf area was measured using leaf area meter (LI-COR model-3100).

They were dried in an oven at 80°C and calculated SLA. Total soluble protein in leaves was estimated using Bovine Serum Albumin as the standard (Sadasivam and Manickam, 1996).

Water use efficiency (Transpiration efficiency) has been estimated as per Wright *et al.* (1995), as follows:

WUE = K/(ei-ea) where K is the constant of proportionality and (ei-ea) the average vapour pressure deficit (VPD).

K = 14.4 -0.53 ( ), being the relationship of K with actually measured, where is the carbon isotope discrimination.

Δ= 0.03 (SLA) + 14.0, being the interrelationship of with actual SLA values.

Carbon isotope discrimination ($\Delta^{13}C$) was determined at 60 DAS. Third leaf from the top on primary axis of the sampled plants were collected, bulked, oven dried and then ground to fine powder. CID in the ground leaf samples was measured by Isotopic Ratio Mass Spectrometer (IRMS) at the National Facility for quantification of stable isotopes in the Department of Crop Physiology, UAS, GKVK Campus, Bangalore as described by Hubick *et al.* (1986).

Results and discussion

SLA ranged between 132.1 (Tir 16) to 180.0 cm^2/g (Tir 8) at 60 DAS (Table 1). Nageswara Rao and Wright (1994) reported that, in groundnut, genotypes with lower SLA (thicker leaves) had more photosynthetic machinery and the potential for greater assimilation per unit leaf area. In the present study SLA (which is negatively related to leaf thickness) is negatively correlated with WUE (r = -0.89, P<0.05) (Fig 1a) Wright *et al.* (1993) reported similar relationship between WUE and SLA. These observations are consistent with our earlier hypothesis that, cultivars with high WUE have higher photosynthetic capacity.

Carbon isotope discrimination ($\Delta^{13}C$) values had a range of 18.2 to 20.2 0/00 under stress condition representing a significant variability among tested genotypes with Tir 16 having the lowest and Tir 8 having the highest $\Delta^{13}C$ (Table 1). Earlier observations in the *Arachis* species (Hubick *et al.*, 1986; Wright *et al.*, 1988; 1993) suggested that variation in photosynthetic capacity/unit leaf area could be largely responsible for genotypic variation in 13C. Plants discriminate against the heavy isotope of carbon ($\Delta^{13}C$) during the process of photosynthesis. However the extent of discrimination depends on the pi (intercellular CO_2 partial pressure) and hence $\Delta^{13}C$ content in the plant samples has emerged as a potential tool to quantify pi and WUE. Since pi/pa ratios predominantly determine the variations in WUE and $\Delta^{13}C$, a strong relationship between $\Delta^{13}C$ and WUE can be expected. A significant negative relationship between $\Delta^{13}C$ and WUE (r =-0.89, P<0.05) has been observed in the present study (Fig 1b). Significance and biochemical basis of $\Delta^{13}C$ and the relationship of $\Delta^{13}C$ with WUE were extensively studied (Farquhar *et al.*, 1989; Read *et al.*, 1991).

Total soluble protein in leaves at 60 DAS, varied significantly among genotypes ranging between 1.60 in Tir 8 to 3.05 mg/g fresh weight in Tir 16 (Table 1). Strong positive relationship was observed between WUE and total soluble proteins (r = 0.62, P<0.05) (Fig 1c). Since SLA is negatively correlated with WUE, it is possible that a genotype with high soluble protein and Rubisco content may have high WUE by virtue of higher assimilation rate (Conner *et al.*, 1993).

Significant variation exhibited in total dry matter production (10.3 to 24.8 g/plant) and pod yield (8.20 to 15.0 g/plant) (Table 1) in groundnut genotypes The genotypic variation in WUE ranged from 2.10 to 2.93 g/kg under stress condition at 60 DAS in the present investigation (Table 1). Genotype Tir 16 recorded highest WUE as compared to all other tested genotypes. It is well documented that, in groundnut, differences in WUE is mainly associated with assimilation efficiency rather than stomatal conductance (Hubick *et al.*, 1986; Wright *et al.*, 1988;). WUE showed significant positive relationship with total dry matter production (r = 0.98, P<0.05) (Fig 1d) and pod yield (r= 0.86, P<0.05) (Fig 1e). More than 92% of the variation in dry matter production was accounted due to its variation in WUE suggesting the importance of WUE in determining crop productivity (Hebber *et al.*, 1994). The superiority in kernel yield was accompanied with superiority in harvest index, WUE and transpiration either alone or in combination (Nagda *et al.*, 2003). For achieving maximum yield, an optimum combination of these traits (WUE, T and HI) is required. However, Jayalakshmi *et al.*, (1998) have observed no significant relationship between WUE and pod yield in F_3 material indicating the possibility for concurrent improvement of both the traits.

The present study reveals that in groundnut significant genotypic variations were observed in WUE and physiological parameters (SLA, $\Delta^{13}C$ and total soluble proteins). Among the genotypes, Tir 16 recorded highest total dry matter, total soluble protein content, WUE and lowest SLA value (thus low $\Delta^{13}C$ value) compared to other genotypes. Results suggests that SLA, $\Delta^{13}C$ and total soluble proteins can be used as surrogate measures to identify high water use efficient genotype and can be used as a selection trait in breeding for drought tolerant genotypes.

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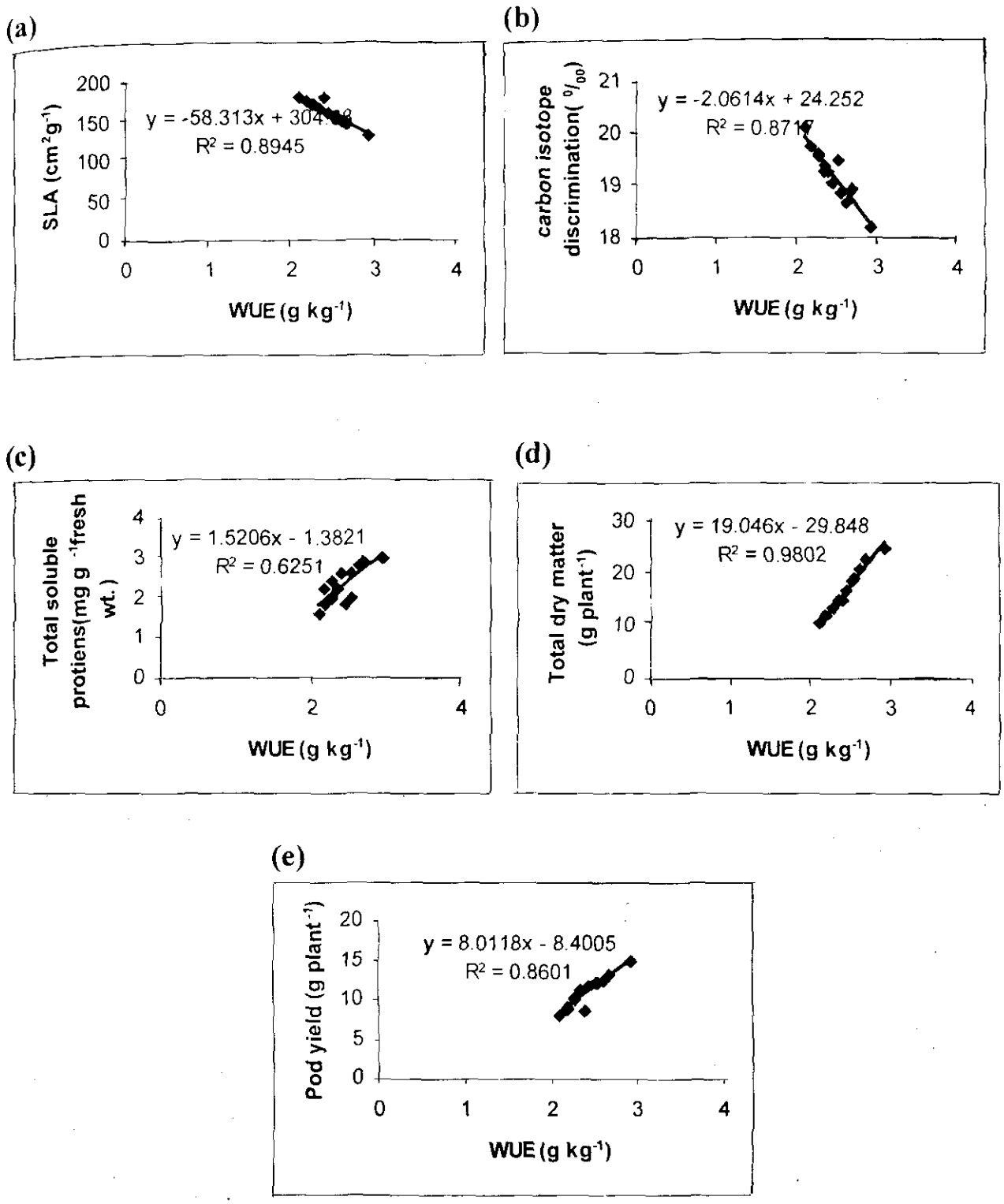

Fig. 1. Correlation between WUE and physiological parameters

Table 1 Specific leaf area, carbon isotope discrimination ($\Delta^{13}C$), total soluble proteins, drymatter, water use efficiency and pod yield in groundnut genotypes at 60 DAS

Genotypes	SLA (cm^2/g)	$\Delta^{13}C$ ($^0/_{00}$)	Total soluble proteins (mg/g fresh weight)	Dry matter (g/plant)	WUE (g/kg)	Pod yield (g/plant)
Tir 7	165.7	19.36	2.21	14.7	2.35	11.1
Tir 8	180.6	20.11	1.61	10.3	2.10	8.05
Tir 12	170.5	19.54	2.00	13.3	2.27	10.2
Tir 10	170.1	19.56	2.01	13.3	2.28	10.0
Tir 11	175.6	19.74	1.82	11.8	2.18	9.01
Tir 13	150.3	18.65	2.81	20.7	2.62	12.5
Tir 14	146.2	18.91	2.90	22.7	2.69	13.1
Tir 15	165.8	19.25	2.20	14.7	2.35	11.2
Tir 16	132.1	18.20	3.01	24.8	2.93	15.2
Tir 17	154.8	18.85	2.60	18.8	2.54	12.2
ICR 1	170.7	19.61	2.41	13.3	2.27	10.0
ICR 3	160.6	19.02	1.81	16.8	2.44	11.6
ICR 7	175.6	19.73	2.21	11.7	2.18	8.90
ICR 8	165.8	19.27	2.61	14.8	2.35	11.3
ICR 21	155.6	19.50	2.00	18.7	2.53	12.1
Mean	163.2	19.29	2.28	15.9	2.40	11.0
SEm	1.02	0.018	0.024	0.16	0.054	0.36
CD (P=0.05)	2.86	0.053	0.067	0.45	0.15	1.00

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Evaluation of different methods of micronutrient application in groundnut, *Arachis hypogaea*

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Abstract

An experiment was carried out at College Farm of Anand Agricultural University, Anand to compare the effect of method of micronutrient application on yield and uptake by *kharif* groundnut during, 1999-2002. The micronutrients in the form of formulations for seed treatment were tested with two sources of elements *viz.*, Zn, Mn and Mo and compared with standard recommended soil/foliar application of individual micronutrient. The seed treatment with solutions each of Zn, Mn and Mo was made to groundnut seed @ 16, 12 and 6 ml/kg containing 30, 25 and 12.5% of Zn, Mn and Mo, respectively. The groundnut pod, haulm and total yields were increased significantly over control under different treatments. The seed treatment with ZnO @ 16 ml/kg seeds containing 30% Zn was also comparable in increasing yield of groundnut with soil application of $ZnSO_4$ @ 5 kg Zn/ha. In case of Mn, the seed treatment @ 12 ml/kg seed containing 25% Mn through MnO_2 increased groundnut pod yield by about 2 q/ha over control. Similarly, the seed treatment with ammonium molybdate @ 6 ml/kg seed of 12.5% Mo concentration was also found superior over other Mo treatments to increase pod, haulm and total yields. The uptake of micronutrients by groundnut was significantly higher over control due to application of micronutrients.

Key words: Seed treatment, micronutrients, Zn, Mn, Mo, groundnut

Introduction

Micronutrients deficiency is wide spread in India because of intensive cropping system and use of micronutrient free fertilizers in the present day agriculture. Intensively cultivated soils at various fertility levels in long run may alter micronutrient status of soil to cause imbalance in nutrition in crops which necessitates supplementation of micronutrients for higher crop yields (Patel *et al.*, 1999). Application of micronutrients through seed treatment nourishes crops at critical early stages and helps in crop growth. Further, the correction of micronutrient deficiency through seed treatment is comparatively cheaper than foliar/soil application and also helps in reducing the load of inorganic chemicals. Keeping this in view, the present study was conducted to evaluate efficacy of method of micronutrient application.

Materials and methods

The investigation was carried out at the Anand Agricultural University, Anand to compare the different methods of micronutrient applications on groundnut in *kharif* during 1999-2002 in loamy sand (Typic Ustocherepts) of Anand. The seed treatment with the formulations were tested for two sources of Zn, Mn and Mo. The soil of the experimental field was nearly alkaline in nature (pH 7.9) and soluble salt (EC 0.39 dS/m) content was within the safe limit. The total N content was low and overall fertility status of the soil was found medium. The DTPA-extractable Fe (5.3 mg/kg), Mn (6.3 mg/kg) and Zn (0.71 mg/kg) were marginal while Cu (1.40 mg/kg) was sufficient (Dangarwala *et al.*, 1994). Acid ammonium oxalate (Purvis and Peterson, 1956), Mo (0.086 ppm) was marginal according to Dangarwala *et al.* (1994). In all 10 treatments were tested under Randomised Block Design with three replications which included concentrated micronutrient formulations of Zn, Mn and Mo along with standard recommended soil/foliar application of individual micronutrient.

For the seed treatment groundnut seeds were coated with formulations each of Zn, Mn and Mo solutions @ 16, 12 and 6 ml/kg containing 30, 25 and 12.5% of Zn, Mn and Mo, respectively through different sources as indicated in the respective treatments. Further, the individual soil application of Zn and Mo was given @ 5 kg Zn/ha through $ZnSO_4$ (Zn-21%) and 1 kg Ammonium molybdate (Mo-54%)/ha, respectively. The Mn was given through foliar application @ 1% $MnSO_4$ solution after 30 days of sowing and additional two sprays were given at seven days interval thereafter. The recommended dose 25-50-0 of NPK were applied uniformly to all the plots. The standard analytical procedures were followed for the soil and plant samples analysis (Lindsay and Norvell, 1978; Jackson, 1979).

Results and discussion

The soil application of 5 kg Zn/ha increased groundnut pod yield over control and it was significantly superior to rest of the treatments (Table 1). The superiority of soil

application of Zn has been indicated by several workers. Gupta (1995) also noticed that soil application of Zn was more beneficial than seed coating of groundnut with Zn solution. In case of seed treatment of Zn, ZnO coating enhanced groundnut yields significantly over control. The results are in the line of those reported by Geetha *et al.* (1996). All Mn treatments *viz.*, spray of 1% $MnSO_4$ as well as seed treatments with $MnCl_2$ and MnO_2 @ 12 ml/kg of seed gave significantly higher pod yield over control. Highest pod yield was recorded when Mn was applied through seed treatment with MnO_2. In case of Mo, maximum and significantly higher pod yield over control was observed under the seed treatment with ammonium molybdate @ 6 ml/kg seed being at par with other treatments (Table 1). The improvement in groundnut yield with Mo seed treatment has also been reported by several workers (Wankhede *et al.*, 1992; Gowda *et al.*, 1994; Geetha *et al.*, 1996; Sahu *et al.*, 1998).

Further, the highest haulm and total yield were also noticed due to soil application of 25 kg $ZnSO_4$/ha. The spray of 1% $MnSO_4$, seed treatments of $MnCl_2$, MnO_2, ammonium molybdate and sodium molybdate could improve the haulm yield significantly over control. The response by groundnut to soil application of Zn was maximum (3 q/ha) followed by nearly 2 q/ha due to seed treatments of Mn and Mo through MnO_2 and ammonium molybdate, respectively. The response to Zn, Mn and Mo application is mainly attributed to the marginal availability of these elements in the soils.

Uptake of micronutrients: The utilization of micronutrients by the different components was higher due to all the treatments and maximum was noticed under treatment of soil application of Zn. The results were in the line of those reported by Geetha *et al.* (1996). The uptake of Mn improved significantly under 1% $MnSO_4$ in all the three cases *viz.*, kernel, haulm and total drymatter. Higher uptake of Mn due to seed treatment was also in accordance with those reported by Garbanov (1995). The maximum utilization of Fe, Zn and Cu was due to soil application of Zn, while that in Mn it was due to spray application of 1% $MnSO_4$ (Table 2). In general, the micronutrients application improved yield and altered their contents to result into higher utilization by the groundnut.

Soil status: The soil status of micronutrients at the end of the experiment (after three years) showed slight changes in available micronutrient content, however, the changes were not significant (Table 3). Therefore, the supplementation of these nutrients was found necessary and there was practically no build up or depletion. The supplementation of Zn through soil application while Mn and Mo through seed treatment could be a better alternative to the traditional mode of applications to receive the similar beneficial effects in groundnut due to favourable economics by reduction in cost for spray and chemicals which in turn could improve soil quality in long run.

The results of the study indicated that among Zn treatments, soil application was superior while Mn and Mo application with MnO_2 and ammonium molybdate as seed treatment, respectively was more beneficial and economical in groundnut for higher yields.

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Table 1 Effect of Zn, Mn and Mo application on groundnut yields (Pooled: 1999-2002)

Treatment	Yield (kg/ha)			Response in pod yield	
	Pod	Haulm	Total	kg/ha	%
Control	1111	2552	3663	-	-
5 kg Zn/ha	1421	3205	4626	310	27.9
Seed treatment ZnO	1298	2769	4067	187	16.8
Seed treatment $ZnSO_4$	1205	2759	3965	94	8.5
1% $MnSO_4$	1299	3085	4384	188	16.9
Seed treatment $MnCl_2$	1214	2962	4177	103	9.3
Seed treatment MnO_2	1319	3074	4393	208	18.7
1 kg Ammonium molybdate/ha	1269	2714	3983	158	14.2
Seed treatment Ammonium molybdate	1278	2943	4221	167	15.0
Seed treatment sodium molybdate	1248	2838	4085	137	12.3
SEm±	35.41	95	101	-	-
CD (P=0.05)	100	269	287	-	-
CV (%)	8.43	9.57	7.08	-	-

Table 2 Effect of Zn, Mn and Mo application on uptake of micronutrients (g/ha) by groundnut (Pooled : 1999-2002)

Treatments	Fe			Mn			Zn			Cu		
	Kernel	Haulm	Total	Kernel	Haulm	Total	Kernel	Haulm	Total	Kernel	Haulm	Total
Control	39.8	1212	1252	10.6	71.6	82.3	22.0	63.4	85.4	8.4	17.8	26.2
5 kg Zn/ha	49.5	1653	1702	13.2	94.4	107.6	30.0	86.4	116.4	9.9	23.7	33.6
Seed treatment ZnO	42.4	1585	1628	12.0	87.0	99.1	24.9	75.5	100.5	9.2	21.5	30.8
Seed treatment $ZnSO_4$	41.6	1503	1545	12.1	89.7	101.9	27.8	75.0	102.8	9.3	19.0	28.3
1% $MnSO_4$	43.7	1488	1532	12.7	161.0	173.8	27.2	71.7	99.0	9.8	21.7	31.2
Seed treatment $MnCl_2$	40.6	1496	1537	11.7	91.2	102.9	26.5	73.9	100.4	9.3	22.0	31.3
Seed treatment MnO_2	43.1	1467	1510	12.0	86.7	98.7	26.0	78.7	104.7	9.7	21.3	31.1
1 kg Ammonium molybdate/ha	44.1	1495	1539	11.2	83.2	94.5	26.5	70.4	97.0	9.5	19.5	29.0
Seed treatment Ammonium molybdate	47.3	1510	1558	11.8	91.2	103.0	25.5	79.0	111.2	9.3	20.0	29.3
Seed treatment sodium molybdate	45.2	1487	1532	12.7	89.1	101.9	25.5	79.1	104.6	9.0	20.8	29.8
SEm±	2.29	62.2	61.9	0.59	13.5	13.6	1.2	3.6	4.3	0.3	1.2	1.3
CD (P=0.05)	NS	175.6	175.1	NS	40.1	40.3	3.4	10.2	12.2	NS	NS	3.8
CV (%)	16.2	11.9	11.6	14.5	17.4	15.4	13.6	14.1	11.7	11.8	11.3	8.9

Table 3. Effect of micronutrient formulations on soil status (mg/kg)

Treatment	Fe	Mn	Zn	Cu
Initial	5.3	6.3	0.71	1.40
Control	5.2	7.1	0.95	1.36
5 kg Zn/ha	6.0	8.7	1.07	1.45
Seed treatment ZnO	5.8	7.8	1.06	1.60
Seed treatment $ZnSO_4$	5.6	8.4	0.95	1.60
1% $MnSO_4$	5.5	7.1	0.83	1.26
Seed treatment $MnCl_2$	5.9	8.5	0.97	1.38
Seed treatment MnO_2	6.0	8.2	0.90	1.39
1 kg Ammonium molybdate/ha	5.0	7.2	0.80	1.27
Seed treatment Ammonium molybdate	5.5	7.7	0.83	1.35
Seed treatment sodium molybdate	5.1	7.2	0.90	1.48
SEm±	0.50	0.61	0.10	0.11
CV (P=0.05)	NS	NS	NS	NS
CV (%)	15.7	13.3	19.3	13.2

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Effect of applied nutrients on major (NPK) and secondary (Ca, Mg, S) nutrients concentration at different growth stages of rainfed groundnut, *Arachis hypogaea* L. in alfisols*

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Abstract

A field experiment was conducted on red sandy loam soil during *kharif*-2002 and 2003 at Regional Agricultural Research Station, Tirupati, Andhra Pradesh. The NPK concentrations of index leaf were highest at flowering stage and gradually decreased till harvest. The uptake of nutrients was highest at harvest with the application of organic and inorganic fertilizers. Higher concentrations of Ca, Mg and Sulphur were observed in NPK alone applied plots or NPK in combination with gypsum or lime or $ZnSO_4$. Application of SSP alone or gypsum was unable to meet Ca requirement of the crop, as it was evident from the low Ca concentration of leaf at pod development and harvest stages. Concentration of Mg in index leaf *was more at flowering and harvest stages than at pod* development stage. No antagonistic effect of Ca and K was observed on concentration and uptake of Mg. Highest S concentration was observed at pod development stage and it was more pronounced with the application of NPK along with gypsum or $ZnSO_4$. Similar trend was noticed with respect to S uptake.

Key words: Manure, fertilizers, nutrient concentrations, growth stages, groundnut

Introduction

Groundnut is the major oilseed crop grown under rainfed conditions in AP. The crop suffers from inadequate/I mbalanced nutrient supply because many farmers of the Rayalaseema region of AP belief that application of chemical fertilizer may not be utilized by crop under moisture stress conditions. Hence an experiment was laid out to study the effect of nutrients on yield and nutrient *concentration and uptake in rainfed groundnut.*

Material and methods

A field experiment was conducted during *kharif* 2002 and 2003 in dry land farm of Regional Agricultural Research station Tirupati, A.P in a randomized complete block design with eleven treatments and four replications. The test crop was groundnut, variety Tirupati-1. NPK were *applied basally in the form of urea, SSP and MOP* respectively as per the treatments. Gypsum and lime were applied at first bloom stage i.e., 30 DAS. The plant analyses for N (AOAC, 1970), P and K (Jackson, 1973) and Ca, Mg and S (Vogel, 1978) was done with standard methods and nutrient uptake was calculated.

Results and discussion

Application of FYM and inorganic fertilizers significantly influenced the N, P, K concentrations in index leaf at different stages of the crop and uptake at harvest (Table 1 and 3). Higher N concentration was observed in treatment, which received, N along with P or K irrespective of the stages of crop growth. Concentration of N was maximum at flowering stage and there after decreased at harvest. This might be due to more N requirement during the period of flowering to pod development. The N concentration declined in the index leaf at pod development stage probably due to translocation of N from leaves to pod. Similar results were reported by Bhaskara *Reddy et al. (1992). The N uptake at harvest of the plant* was significantly influenced by the treatments and it was highest in N received treatments along with P (T_7) and was on par with NPK, NPK+ gypsum, NPK + lime and NPK + gypsum + zinc sulphate in both the seasons.

Phosphorus concentration in index leaf and uptake at harvest was significantly varied with treatments at different growth stages. In both the years phosphorus concentration was higher at flowering stage in the treatments *viz.*, N, P, NPK + lime, NPK + gypsum and NPK + gypsum + $ZnSO_4$. The concentration of phosphorus decreased from flowering to pod development stage and again marginally increased at harvest of the crop. Higher concentration at flowering stage may be due to absorption from the soil which reached maximum at flowering stage and slowly declined in the concentration as the crop growth advanced. This may be due to dilution effect in plants and accumulation in kernels at pod development and maturity

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stages. Earlier Loganathan and Krishnamoorthy (1977) who reported that groundnut crop grown in red soils absorbed 10% of phosphorus at vegetative stage and 40-50% at reproductive stage, and remaining at reproductive to harvest of the crop. The higher phosphorus uptake was observed in NPK, NPK + gypsum, NPK + lime and NPK + gypsum + $ZnSO_4$, can be attributed to higher phosphorus concentration and dry matter production in these treatments.

The higher values of potassium concentrations and uptake were noticed in treatments, which received potassium along with N or P or combination at all the growth stages. This may be due to synergistic effect of nutrients. The concentration of potassium was gradually decreased from flowering to harvest and it was more pronounced between the pod development to harvest stage. This might be due to transfer of potassium from leaves to pods/kernels. Addition of sulphur through SSP, gypsum or $ZnSO_4$ increased the potassium concentration in all the crop growth stages and these treatments recorded higher potassium concentration at all crop growth stages. This may be due to synergistic effect of sulphur on potassium (Mariswamy Gowda *et al.*, 2001). The decreasing trend of potassium concentration from reproductive stage to harvest of the crop (maturity) due to transfer of potassium from leaves to pods was also earlier reported by Patra *et al.* (1998).

Application of manure and fertilizers brought significant variations in leaf concentration as well as uptake of Ca, Mg and S at different stages of crop growth (Table 2). Higher values of Ca, Mg and S was observed in NPK + Gypusm + $ZnSO_4$, NPK + lime, NPK + gypsum and NPK treatments. Application of calcium either through SSP or gypsum or lime along with nitrogen and phosphorus significantly increased calcium concentration in plants. This was supported by the findings of Patra *et al.* (1995) in groundnut. The leaf calcium concentration was recorded highest at flowering stage and gradually decreased at pod development stage and maintained a similar level at harvest of the crop. The results clearly indicated that calcium component of SSP (10 kg P/ha) or gypsum (250 kg/ha) was not sufficient to meet the calcium requirement of crop. The calcium uptake at harvest of the crop was higher in the treatments, which received gypsum or lime or $ZnSO_4$, along with NPK. These results corroborated with the findings of Bhaskara Reddy *et al.* (1992) in groundnut.

Table 1 Effect of applied nutrients on major nutrients concentration (%) in index leaf of rainfed groundnut at different growth stages

Treatment	*Kharif* 2002									*Kharif* 2003								
	N			P			K			N			P			K		
	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest
T_1	3.70	1.87	1.63	0.14	0.03	0.08	1.36	1.15	0.73	3.77	1.90	1.77	0.084	0.05	0.05	1.21	1.09	0.71
T_2	4.02	2.11	1.93	0.19	0.05	0.09	1.53	1.18	0.84	4.29	2.09	2.24	0.09	0.05	0.05	1.23	1.14	0.78
T_3	3.76	2.29	2.02	0.17	0.04	0.08	1.38	1.13	0.81	4.20	2.26	2.29	0.11	0.05	0.05	1.27	1.13	0.72
T_4	3.77	2.23	1.86	0.19	0.06	0.09	1.45	1.15	0.81	4.12	2.25	2.39	0.13	0.06	0.06	1.24	1.10	0.74
T_5	3.72	2.05	1.66	0.16	0.04	0.09	1.53	1.19	0.78	3.98	2.18	2.27	0.11	0.05	0.05	1.32	1.11	0.75
T_6	3.80	2.21	1.90	0.17	0.05	0.10	1.56	1.18	0.79	4.23	2.5	2.21	0.11	0.07	0.06	1.28	1.09	0.77
T_7	3.95	2.25	1.84	0.19	0.06	0.10	1.42	1.12	0.83	4.13	2.06	2.47	0.11	0.07	0.06	1.25	1.06	0.77
T_8	4.04	2.13	1.85	0.18	0.07	0.10	1.56	1.18	0.86	4.31	1.98	2.44	0.12	0.07	0.07	1.28	1.13	0.80
T_9	4.07	2.25	1.95	0.18	0.07	0.10	1.39	1.17	0.82	4.37	2.08	2.37	0.13	0.07	0.08	1.27	1.09	0.79
T_{10}	4.17	2.27	1.89	0.18	0.07	0.10	1.47	1.19	0.83	4.33	2.14	2.21	0.12	0.07	0.08	1.27	1.07	0.82
T_{11}	4.22	2.34	1.98	0.20	0.08	0.11	1.50	1.19	0.88	4.36	2.29	2.30	0.13	0.08	0.08	1.28	1.10	0.92
Mean	3.93	2.18	1.94	0.18	0.06	0.09	1.47	1.17	0.82	4.19	2.13	2.27	0.112	0.06	0.06	1.28	1.10	0.78
SEm±	0.03	0.47	0.03	0.002	0.01	0.01	0.03	0.002	0.03	0.07	0.07	0.08	0.01	0.01	0.01	0.02	0.02	0.04
CD (P=0.05)	0.10	0.13	0.09	0.02	0.01	0.02	0.09	0.007	NS	0.18	0.19	0.24	0.02	0.02	0.02	0.05	0.04	NS

T_1 : Control (No fertilizer); T_2 : FYM @ 5 t/ha (once in 3 years); T_3 : 20 kg N/ha;
T_4 : 10 kg P/ha; T_5 : 25 kg K/ha; T_6 : 250 kg gypsum/ha as top dressing;
T_7 : T_3 + T_4; T_8 : T_3 + T_4 + T_5; T_9 : T_3 + T_4 + T_5 + 250 kg gypsum/ha;
T_{10} : T_3 + T_4 + T_5 + 100 kg lime/ha; T_{11} : T_3 + T_4 + T_5 + 25 kg zinc sulphate (as basal, once in 3 years) + 250 kg gypsum/ha as top dressing

Table 2 *Effect of applied nutrients on secondary nutrients concentration (%) in index leaf of rainfed groundnut different growth stages*

Treatment	*Kharif* 2002									*Kharif* 2003								
	Ca			Mg			S			Ca			Mg			S		
	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest	Flowering	Pod development	Harvest
T_1	1.78	1.21	1.13	0.51	0.24	0.62	0.18	0.28	0.27	1.44	1.21	1.15	0.59	0.23	0.61	0.18	0.29	0.26
T_2	1.94	1.53	1.64	0.72	0.37	0.66	0.21	0.35	0.32	1.67	1.24	1.61	0.67	0.34	0.71	0.21	0.32	0.28
T_3	2.10	1.41	1.62	0.66	0.35	0.65	0.20	0.29	0.29	1.89	1.22	1.59	0.70	0.32	0.64	0.22	0.30	0.29
T_4	1.96	1.61	1.63	0.62	0.39	0.72	0.22	0.39	0.36	1.86	1.65	1.62	0.64	0.41	0.74	0.25	0.32	0.30
T_5	2.12	1.45	1.55	0.70	0.35	0.66	0.22	0.35	0.34	1.74	1.40	1.54	0.64	0.36	0.63	0.22	0.34	0.32
T_6	2.41	1.47	1.70	0.61	0.47	0.62	0.26	0.37	0.36	2.15	1.48	1.67	0.63	0.47	0.61	0.26	0.35	0.35
T_7	2.14	1.54	1.56	0.76	0.48	0.72	0.29	0.38	0.35	2.05	1.54	1.61	0.66	0.51	0.72	0.29	0.38	0.36
T_8	2.47	1.64	1.95	0.52	0.41	0.66	0.31	0.38	0.37	2.19	1.65	1.70	0.74	0.44	0.72	0.27	0.39	0.37
T_9	2.41	1.63	2.02	0.55	0.47	0.71	0.30	0.39	0.39	2.23	1.65	2.04	0.81	0.45	0.80	0.31	0.41	0.40
T_{10}	2.38	1.51	2.08	0.66	0.58	0.76	0.31	0.41	0.41	2.25	1.63	2.05	0.84	0.60	0.82	0.31	0.40	0.42
T_{11}	2.56	1.66	2.16	0.78	0.59	0.78	0.31	0.43	0.42	2.47	1.67	2.11	0.90	0.60	0.85	0.32	0.46	0.42
Mean	2.21	1.51	1.73	0.64	0.42	0.69	0.25	0.37	0.35	2.08	1.48	1.73	0.71	0.43	0.72	0.26	0.36	0.34
SEm±	0.09	0.04	0.11	0.05	0.03	0.04	0.004	0.004	0.003	0.30	0.03	0.05	0.06	0.02	0.01	0.004	0.003	0.003
CD (P=0.05)	0.24	0.12	0.30	0.15	0.09	NS	0.01	0.01	0.01	0.88	0.07	0.14	0.18	0.06	0.02	0.01	0.01	0.01

Table 3 Effect of applied nutrients on nutrient uptake (kg/ha) in rainfed groundnut at harvest

Treatment	*Kharif 2002*						*Kharif 2003*					
	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
T_1	29.0	1.3	12.4	19.2	10.6	4.6	39.3	1.1	15.8	25.5	13.5	5.8
T_2	56.1	2.6	23.1	45.2	18.1	9.0	70.4	1.9	28.0	57.9	25.6	9.9
T_3	46.4	1.7	18.2	36.4	14.7	6.4	77.6	1.8	24.5	53.8	21.7	9.8
T_4	53.1	2.6	22.6	45.4	20.3	10.1	96.7	2.6	29.7	65.6	29.8	12.1
T_5	40.7	2.0	18.3	36.2	15.5	8.1	78.7	1.9	26.0	53.3	21.6	11.1
T_6	44.8	2.3	18.7	39.9	14.8	8.5	76.1	2.2	26.4	57.3	21.0	11.9
T_7	54.4	2.9	23.4	44.0	20.3	10.0	105.2	2.7	33.0	69.0	30.8	15.4
T_8	55.0	3.0	24.9	56.1	19.1	10.7	105.1	3.0	34.5	73.2	30.9	15.8
T_9	59.6	2.9	22.9	56.9	19.9	10.6	103.4	3.5	34.6	88.8	35.0	17.2
T_{10}	59.3	3.0	24.4	61.1	22.4	12.0	98.1	3.3	36.7	91.8	37.5	18.5
T_{11}	61.1	3.3	26.0	64.0	23.2	12.4	103.3	3.8	41.3	94.8	38.2	19.0
Mean	50.6	2.5	21.3	45.9	18.1	9.3	86.7	2.5	30.3	66.3	27.7	13.3
SEm±	1.6	0.2	1.1	3.2	1.3	0.2	5.6	0.4	2.6	3.7	1.0	0.4
CD (P=0.05)	4.7	0.6	3.2	9.2	3.9	0.7	16.1	1.1	7.8	10.8	2.9	1.3

The magnesium concentration of the index leaf increased at flowering and maturity stages of the crop, while it was lower in pod development stage. Further, the antagonistic effect of application of Ca and K at the doses applied was not observed on the concentration and uptake of magnesium but increased concentration and uptake of magnesium by the application of calcium, phosphorus and sulphur containing fertilizers was observed. Similar results were reported by Bhaskara Reddy *et al.* (1992).

The data on sulphur concentration and uptake by groundnut revealed that the highest concentration of the sulphur was observed at pod development stage, and then decreased at harvest in both the seasons. This trend may be due to absorption from the soil was more at pod

development stage (Mishra and Singh, 1989). Application of P through SSP maintained the sufficient level of sulphur in index leaf at all the stages of the crop. Application of NPK along with $ZnSO_4$ and gypsum significantly increased the sulphur content of the leaf at pod development and at harvest of the crop. Application of SSP or gypsum alone without nitrogen did not increase sulphur concentration in plant. The highest uptake of sulphur was noticed in the treatment which received sulphur through SSP, gypsum and $ZnSO_4$ along with N and P. This was supported by the findings of Nayak *et al.* (2004). It is concluded that the NPK concentration of index leaf were highest at flowering stage and gradually decreasing at harvest. The uptake was highest at harvest with the application of organic and inorganic fertilizers. Higher concentrations of Ca, Mg and S were observed in NPK alone applied plots or NPK in combination with gypsum or lime or $ZnSO_4$. Application of SSP alone and gypsum was unable to meet calcium requirement of the crop as it was evident from the low calcium concentration of index leaf at pod development and harvest stages. Concentration of Mg in index leaf was more at flowering and harvest stage than at pod development stage. Sulphur concentration was sufficient at pod development stage with the application of NPK along with gypsum or $ZnSO_4$.

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Influence of irrigation schedules and sand application on *rabi* groundnut, *Arachis hypogaea* L. in deep black soils of upper Krishna command area in Karnataka

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Abstract

A field investigation was conducted in vertisol at college of Agriculture, Bheemarayanagudi during *rabi* seasons 1999-2000 and 2000-2001 to find the effect of irrigation schedules and sand application on *rabi* groundnut pod yield and its effect on chemical properties of the soil and uptake of nutrients. Results indicated that scheduling of irrigations at pre flowering, flowering, pegging, pod formation and pod filling stages along with sand mulching @ 45 t/ha or sand incorporation @ 45 t/ha recorded significantly higher pod yield of groundnut over no sand application with similar irrigation schedules. Highest net return was realised in five irrigations at critical stages with sand mulching @ 45 t/ha with B:C ratio of 2.73 or sand incorporation @ 45 t/ha with B:C ratio 2.61. The nutrient uptake was also higher in five irrigations at critical stages with sand mulching @ 45 t/ha or sand incorporation @ 45 t/ha compared to no sand application. Sand application with five irrigations at critical stages also improved the physical conditions of the soil.

Key words: Groundnut, *Arachis hypogaea* L., irrigation schedules, deep black soils and sand application

Introduction

The Upper Krishna project (UKP) command area has an irrigation potential of 0.8 m ha accounting to 17 % of the total irrigated area in Karnataka state. The ill-drained black soils having clay content (62 %) provided ideal niches for water logging and salinity. These problems have led to research on development of specific land and water management technologies on sound scientific base. Drainage and irrigation are inseparable and former needs due attention when irrigation is initiated. Apart from costly open and tile drains, emphasis to improve in situ water dynamics through addition of high density coarse material such as sand that improves soil physical condition is necessary. Hence, scheduling of irrigation to optimize the water supply according to crop need and improvement of physical conditions such as per cent aggregate stability, basic infiltration rate and bulk density with addition of sand to the soil have been tried in groundnut during *rabi* seasons.

Materials and methods

Field experiment was conducted to study the response of *rabi* groundnut to irrigation schedules and sand application in the deep vertisols during rabi seasons 1999-2000 and 2000-01 at the College of Agriculture, Bheemarayanagudi. The experimental soil has bulk density 1.32 g/cm^3, porosity 50%, and infiltration rate 0.75 cm/hr. The main plot (irrigation schedules) and sub plot treatments (sand application) were imposed as mentioned in the Table 1.

The experiment was laid out in Split Plot Design with 21 treatment combinations and replicated thrice. Sowing was taken up in the month of November, with cv. R-9251. The pod yield and yield components were recorded in five randomly selected plants of each treatment. The soil physical characters like bulk density (g/cm^3), infiltration rate (cm/hr) and aggregate stability (%) were computed.

Results and Discussion

The data indicated that giving five irrigations (I_1) at critical stages recorded significantly higher groundnut pod yield than scheduling irrigation at fortnightly interval (Table 1). This is mainly due to higher number of pods/plant in five irrigations at critical stages over fortnightly irrigations and three irrigations at critical stages (I_2). Similarly, significantly higher pod yield/plant was observed in five irrigations scheduled at critical stages over fortnightly irrigations and three irrigations at critical stages. The phosphorus uptake was significantly higher in five irrigations treatment compared to other treatments (Table 2). The yield increase in five irrigations treatment was 10.38% over fortnightly irrigations. Three irrigations at critical stages treatment recorded significantly lowest yield with reduction of 10.26 % over fortnightly irrigations. The present findings are analogous to those reported by Ved Singh *et al.* (1994). There was a net saving of one irrigation amounting to 6 cm depth of irrigation water over farmers method (fortnightly irrigation). Khade *et al.* (1997) reported 42 % saving in irrigation water with five irrigations at different critical stages over 1.00 IW/CPE ratio. Moisture stress was occurred during peg formation stage with three irrigation

treatment resulting in lower pod yield. Lower pod yield here was attributed to the reduction in total drymatter accumulation, poor growth of pegs into the soil and also due to the dehydration of protoplasm causing reduction in photosynthetic rate. These findings are in agreement with Koti *et al.* (1994) for soybean during water stress. Hence, five irrigations at critical stages helped to maintain sufficient moisture in the soil during peg initiation and pegging stages and also must have helped in the translocation of photosynthates efficiently to the developing pods. The higher pod yield, net returns and B:C ratio (2.42) was recorded in five irrigations (I_1) over other irrigation treatments.

The pooled data of sand application @ 45 t/ha either mulching or incorporation recorded on par and significantly higher groundnut pod yield over no sand application (Table 1). The yield increase was 29.74 % in sand mulching and 22.5% in sand incorporation over no sand application. Chittapur (1982) and Munaswamy *et al.* (1995) observed increase in yield over sand application in *kharif* groundnut. The pod yield increase in sand incorporation @ 45 t/ha as well as sand mulching @ 45 t/ha was mainly attributed to improvement in per cent aggregate stability of the surface soil. In the present study, the aggregate stability of surface soil was 52% in sand incorporation and 70% in sand mulching over no sand application. Soil bulk density value at 0-15 cm surface increased in sand incorporation (1.39 g/cm^3) and in sand mulching (1.38 g/cm^3) as compared to no sand application (1.35 g/cm^3). The basic infiltration rate of surface soil was improved immensely in sand incorporation and in sand mulching over no sand application (Table 3). Similar observations have been made by Taylor and Blake (1979) and Sudha (1999) in *kharif* groundnut. Sand application recorded significantly higher nitrogen phosphorus and potassium uptake in sand mulching @ 45 t/ha and sand incorporation over control (Table 2). This was mainly attributed to increased availability of N, P and K in these treatments. Gale *et al.* (1993) and Bhone *et al* (1994) reported higher availability of nitrogen in soil when compost was used along with mulch. Like wise sand application @ 45 t/ha either mulching or incorporation recorded significantly highest net returns (Rs 15725 and Rs 17329/ha) and B:C ratio (2.30 and 2.30) over other treatments.

Interaction effect of irrigation schedule and sand application was significant. The significantly higher pod yield was observed in five irrigations at critical stages with sand mulching @ rate of 45 t/ha over no sand application which was on par with five irrigations at critical stages with sand incorporation @ 45 t/ha. There was 33.9 and 28.6 % increase in yield in five irrigations at critical stages with sand mulching and sand incorporation @ 45 t/ha respectively. The yield increase was due to higher yield components like pod yield/plant with sand mulching followed by sand incorporation. Significantly higher uptake was recorded in five irrigations at critical stages with sand nitrogen @ 45 t/ha followed by in five irrigations at critical stages with sand incorporation @ 45 t/ha with respect to N and K over no sand application N and K (Table 2). The higher yield with five irrigations either with sand mulching @ 45 t/ha or sand incorporation @ 45 t/ha over five irrigations with no sand application was attributed to higher soil moisture conservationsMay 16, 2007 in these two treatments as against no sand application. The present results are in conformity with the results of Sudha (1999) in groundnut who reported increased pod yield due to conserved soil moisture due to sand mulching. Significantly higher net returns was obtained in five irrigations at critical stages with sand mulching (Rs 21010 with B:C ratio 2.73) over similar irrigations with no sand application (Rs 15036 with B:C ratio 2.52) .

Table 1 Number of pods, pod yield of groundnut as influenced by different irrigation schedules and sand applications (Pooled data of two years)

	Number of Pods /Plant								Pods Yield (g/plant)								Pod yield (kg/ha)							
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean
I_1	9	10	12	9	10	13	8	10	5.4	6.1	7.3	5.1	6.5	7.7	6.1	6.3	1462	1864	2140	1530	1835	2230	1665	1818
I_2	8	9	10	9	8	10	8	9	4.3	4.7	5.8	5.1	5.3	5.8	5.2	5.2	1356	1517	1626	1334	1491	1690	1334	1478
I_3	8	9	12	8	9	12	7	9	5.2	5.7	6.6	5.2	4.7	5.4	5.1	5.4	1354	1643	1793	1473	1756	1968	1514	1647
Mean	8	9	11	8	9	12	8	-	5.0	5.5	6.6	5.1	5.5	6.3	5.5	-	1391	1675	1853	1446	1694	1963	1513	-
For Comparing the means of			SEm ±			CD (P=0.05)				SEm ±				CD (P=0.05)				SEm ±				CD (P=0.05)		
Irrigation Schedules (I)			0.14			0.5				0.13				0.4				45				147		
Sand application (S)			0.11			0.3				0.13				0.4				40				111		
Interaction (I x S)			0.19			0.6				0.22				0.7				70				216		

I_1 - Five irrigations at pre-flowering, flowering pegging, pod formation and pod filling stage;
I_2 - Three irrigations at flowering, pod formation and pod filling stage,
I_3 - Control (fortnightly irrigations), S_1 - Sand incorporation @ 15 t/ha,
S_2 - Sand incorporation @ 30 t/ha, S_3 - Sand incorporation @ 45 t/ha,
S_4 - Sand mulching @ 15 t/ha, S_5 - Sand mulching @ 30 t/ha,
S_6 - Sand mulching @ 45 t/ha, S_7 - No sand application.

Table 2 Number of pods, pod yield of groundnut as influenced by different irrigation schedules and sand applications (Pooled data of two years)

	Nitrogen								Phosphorus								Potassium							
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean
I_1	47	67	139	95	12	113	101	99	11.5	12.3	16.1	11.0	12.5	16.3	5.7	12.2	66	76	89	67	73	97	68	77
I_2	80	85	119	83	95	131	75	96	7.8	5.9	9.3	5.1	4.8	8.4	4.3	6.1	77	102	103	67	87	114	67	81
I_3	85	116	129	47	109	156	53	99	6.9	9.7	9.4	5.4	8.3	11.3	6.8	8.3	71	101	135	67	103	139	68	98
Mean	71	90	129	75	106	140	76	-	7.8	9.3	11.6	7.2	8.5	12.0	5.6	-	72	93	110	67	88	117	68	-
For Comparing the means of			SEm ±			CD (P=0.05)					SEm ±			CD (P=0.05)					SEm ±			CD (P=0.05)		
Irrigation Schedules (I)			1.68			NS					0.31			1.0					3.15			10		
Sand application (S)			2.75			8					0.36			1.0					2.04			6		
Interaction (I x S)			4.80			15					0.63			1.9					3.54			11		

Table 3. Per cent aggregate stability, basic infiltration rate and bulk density of soil at 0-15 cm soil layer as influenced by different irrigation schedules and sand applications (mean of two years)

	Per cent aggregate stability								Basic infiltration rate (cm/hr)								Bulk density (g/cm^3)						
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean	S_2	S_3	S_4	S_5	S_6	S_7	Mean
I_1	43.24	46.57	52.25	44.88	48.76	70.82	41.46	49.71	1.95	3.11	3.96	1.90	3.00	4.01	1.20	2.73	1.22	1.30	1.35	1.22	1.36	1.36	1.25	1.30
I_2	43.54	45.54	50.34	44.54	48.54	69.56	42.54	49.22	1.50	3.16	3.54	1.80	3.11	4.40	1.30	2.73	1.34	1.33	1.41	1.24	1.37	1.41	1.39	1.37
I_3	44.34	47.54	53.30	44.54	49.54	68.56	45.54	50.47	1.70	3.00	3.51	1.95	3.00	4.11	1.20	2.64	1.32	1.41	1.43	1.30	1.35	1.37	1.38	1.37
Mean	43.70	46.55	51.96	44.65	48.95	69.64	43.17	-	1.72	3.10	3.78	1.88	3.04	4.17	1.23	-	1.30	1.37	1.39	1.25	1.36	1.38	1.35	-

These investigations clearly demonstrated that the irrigation scheduling with five irrigations at critical crop stages such as pre-flowering, flowering, pegging, pod formation and pod filling stages, along with sand incorporation/mulching @ 45 t/ha under deep black soils was found the most effective in enhancing the rabi groundnut yield to an extent 33.9%. This is a most suitable, viable, practical and economically feasible technology to be adopted by the farmers of UKP command area to improve ill drainage effect and to increase productivity of rabi groundnut in Karnataka under depleting soil moisture situations.

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Effect of levels of gypsum on yield and yield components of confectionery summer groundnut, *Arachis hypogaea* L. varieties

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Abstract

Groundnut varieties (TGS 1, TKG 19A, TG 22 and ICGS 49) did not differ significantly in number of pods/plant, kernel/pod and shelling percentage due to various levels of gypsum application. However, 100 kernel weight was highest in ICGS 49. Pod yield, kernel yield and harvest index were higher in variety ICGS 49 over TG 22, TKG 19A and TGS 1. Haulm yield was highest in TG 22 followed by ICGS 49. Application of gypsum @ 400 kg/ha significantly increased the number of pods/plant, kernel weight, shelling percentage, oil content, protein content, pod yield, kernel yield, oil yield and harvest index.

Key words: Summer groundnut, gypsum, groundnut varieties

Introduction

Groundnut occupies first place among oilseed crops grown in India with a total production of 8.33 m. tonnes in 2003-04. The requirement of oilseeds for all nutrients in general is high. These nutrients need to be supplied in adequate quantities for high yield. Oilseed crops are highly responsive to sulphur. Approximately 12 kg sulphur is required to produce one tonne of oilseed (Ghosh *et al.*, 2000). Among the various sulphur (S) sources, gypsum has been found an effective and cheap source for groundnut. The beneficial effect of S through gypsum on yield and yield components has been reported by Mandal *et al.* (2005). Number of pods/plant, 100-kernel weight and shelling percentage increased with increase in application of gypsum (Dutta *et al.*, 2001). Gypsum application also has shown a positive response on pod yield, kernel yield and haulm yield (Choi and Ryu, 1991).

Materials and methods

Field experiment was conducted at the Central Research Farm, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India during the summer season of 2001 and 2002. Treatments comprised of 4 varieties i.e., TGS 1, TKG 19A, TG 22 and ICGS 49 and 3 levels of gypsum i.e., 0, 200 and 400 kg/ha. The experimental site is situated at 23.5°N latitude, 89°E longitude and at an elevation of 9.75 m above the mean sea level. The soil of the experimental field was sandy loam in texture having pH of 6.8, organic carbon 0.69%, total N 0.07%, 19.4 kg/ha available P, 190.4 kg/ha available K and 11.92 ppm available sulphur. The crop was sown in the first week of March and harvested in the first week of July in both the years. The number of rows/plot was ten. The experimental design was Factorial Randomised Block with three replications. Seed rate used as 100 kg kernel/ha and seeds were sown in rows spaced at 40 cm. Nutrients applied included 20 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha applied through urea, diammonium phosphate and muriate of potash, respectively. The required quantities of N, P_2O_5 and K_2O and half of gypsum were applied at the time of sowing and the remaining half of gypsum at the time of earthing up at 40 days after sowing. The rainfall received during the experimental period were 580 mm and 485 mm during 2001 and 2002, respectively. Four irrigations were given in 2001 and five irrigations during 2002 at different growth stages. Various yield components such as number of developed pods/plant, kernels/pod and 100-kernel weight, pod yield and haulm yield were taken at harvest and shelling per cent, kernel yield and harvest index were computed.

Results and discussion

The yield-attributing characters like number of developed pods/plant, 100-kernel weight and shelling per cent did not vary significantly with the different varieties. Variety, ICGS 49 recorded maximum values of all parameters followed by TG 22. Application of gypsum gave significant response over control treatment. Number of developed pods/plant, 100-kernel weight and shelling per cent increased with increase in the dose of gypsum upto 400 kg/ha (Table 1). Bandopadhyay and Samui (2000) also observed higher response of gypsum for yield attributing characters of groundnut. Adhikari *et al.* (2003) reported that, application of 400 kg gypsum (400 kg/ha) recorded highest 100-kernel weight, shelling per cent and number of pods/plant. Smyth and Cravo (1992) observed that application of gypsum increased shelling per cent. The findings are also supported by Dutta *et al.* (2001) and Mandal *et al.* (2005). Variety ICGS 49 gave maximum pod yield, kernel yield and harvest index followed by TG 22 whereas, haulm yield was maximum in variety TG 22. Higher pod yield in ICGS 49 was due to higher number of pods/plant and more 100-kernel weight. Application of gypsum @ 400 kg/ha gave highest pod yield, kernel yield, haulm yield and harvest

index for all varieties and was significantly higher over control with respect to harvest index (Table 2). Application of gypsum improved yield components like number of pods, 100-kernel weight and thereby produced higher yield. Bandopadhyay and Samui (2000) reported that gypsum application gave significantly higher pod yield. Similar trend was also observed by Kumaran (2000). Oil content was higher in TG 22 whereas protein content was more in ICGS 49 with high oil yield. Application of gypsum in increasing dosages increased oil content, protein content and oil yield. Choi and Ryu (1991) reported beneficial effect of gypsum application on groundnut.

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Table 1 **Effect of levels of gypsum on yield attributes, yield and harvest index of confectionery groundnut varieties during summer season (pooled data of 2001 and 2002)**

Treatment	Pods/ plant	Kernels/ pod	100-kernel weight (g)	Shelling (%)	Pod yield (kg/ha)	Kernel yield (kg/ha)	Haulm yield (kg/ha)	Harvest index (%)
Varieties								
TGS 1	17	3	64.9	67.4	1843	1244	4607	40.0
TKG 19A	18	2	64.4	67.3	1917	1292	4629	41.3
TG 22	17	2	65.6	67.3	1945	1313	4686	41.5
ICGS 49	19	3	67.9	67.9	2037	1402	4662	43.7
SEm±	0.43	0.12	0.13	0.27	15.1	12.2	20.4	0.31
CD (P=0.05)	NS	NS	0.37	NS	43.1	34.8	58.2	0.91
Level of gypsum (kg/ha)								
0	16	2	63.8	65.2	1725	1137	4491	38.4
200	18	3	65.9	67.6	1964	1331	4700	41.7
400	20	3	67.3	69.7	2116	1475	4749	44.6
SEm±	0.37	0.1	0.11	0.23	13.1	10.6	17.7	0.43
CD (P=0.05)	1.06	NS	0.31	0.66	37.4	30.2	50.5	1.23

NS = Not significant

Table 2 **Effect of levels of gypsum on oil content, protein content and oil yield of confectionery groundnut varieties during summer season**

Treatment	Oil content (%)			Protein content (%)			Oil yield (kg/ha)		
	2001	2002	Pooled	2001	2002	Pooled	2001	2002	Pooled
Varieties									
TGS 1	46.0	45.2	45.6	22.1	21.0	21.6	568	569	568.5
TKG 19A	46.5	46.4	46.4	21.9	21.8	21.9	614	587	600.5
TG 22	45.9	45.9	45.9	22.5	21.3	21.9	620	587	603.5
ICGS 49	47.1	46.4	46.7	22.4	21.7	22.1	669	642	655.5
SEm±	0.12	0.12	0.09	0.16	0.17	0.12	8.54	6.69	5.42
CD (P=0.05)	0.35	0.35	0.25	0.47	0.50	NS	25.04	19.6	15.5
Level of gypsum (kg/ha)									
0	45.3	44.9	45.1	19.8	20.2	19.9	510	511	510.5
200	46.6	46.1	46.3	22.9	21.6	22.3	620	611	615.5
400	47.3	46.9	47.1	24.1	22.6	23.3	720	670	695.0
SEm±	0.11	0.11	0.07	0.14	0.10	0.10	7.39	5.79	4.70
CD (P=0.05)	0.32	0.32	0.20	0.41	0.28	0.28	21.7	16.9	13.4
V x G Interaction									
SEm±	0.21	0.21	0.15	0.28	0.29	0.21	14.8	11.59	9.39

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Response of groundnut, *Arachis hypogaea* L. under different levels of irrigation and zinc

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Abstract

A field experiment was conducted at Agricultural Farm, Institute of Agriculture, Sriniketan, Visva-Bharati, during summer 2003 and 2004 to study the growth and yield of groundnut (cv. AK-12-24) under different levels of irrigation and zinc. Groundnut crop received three irrigations, (branching, peg development and pod development) recorded significantly higher pod yield (18 q/ha), kernel yield (13 q/ha) and oil yield (620.1 kg/ha) and harvest index (67.46%) than under one and two irrigations. Zinc @ 20 kg/ha significantly increased the pod, kernel and oil yields as well as harvest index as compared to 15 and 25 kg/ha. Irrigation applied only at branching and no zinc application recorded the lowest yield and yield attributes. Zinc @ 25 kg/ha significantly lowered the crop productivity might be due to toxicity of zinc.

Key words: Groundnut, irrigation, zinc, yield

Introduction

Groundnut is the second important oilseed crop in India. In West Bengal, it is cultivated mainly as *rabi* and summer crop in an area of 2800 ha with a production of 37900 tonnes. As present India market demands more production of groundnut at a much lower cost of production to face competition with other edible oilseeds and also with other groundnut producing countries. This growth in production may be obtained by increasing productivity with judicious application of fertilizer and irrigation. For increasing productivity, apart form macronutrients, Zinc plays vital role in groundnut production as it is an essential component of over 300 enzymes. Groundnut yield might be hampered under zinc (Zn) deficiency in its soils. Timely irrigation with right quantity improves the productivity of the crop. Information regarding the effect of irrigation and zinc in this red and lateritic belt of West Bengal is also very meager a field experiment was carried out on groundnut.

Materials and methods

The field experiment was conducted at Agricultural Farm, Institute of Agriculture, Sriniketan, Visva-Bharati situated at about 23° 29' N latitude and 87° 42' E longitude at 58.9 m above mean sea level during the summer season of 2003 and 2004. It was conducted on a land with good irrigation and drainage facilities. The soil of the experimental field was sandy loam with pH 5.9, having available N, P, K as 179.2, 29.8, 129.02 kg/ha respectively. The experiment was laid out in Split Plot Design with three replications. Three levels of irrigation applied at branching, peg development, pod development (I_3), two irrigations at branching and peg development (I_2) and one irrigation at branching (I_1) were allotted in main plot whereas levels of zinc *viz.* Zn @ 15 kg/ha, 20 kg/ha and 25 kg/ha as $ZnSO_4$ and control (no zinc application) were allotted in the sub-plots. The treatments combination comprises of 12 plots with 3m x 4m size. General doses of N, P, K @ 30, 60, 40 kg/ha as urea, single super phosphate and muriate of potash respectively were applied as basal. Zinc was applied at the time of sowing. Row to row distance was kept 30 cm and plant to plant distance within the row was 7-10 cm. The crop was irrigated as per treatment and the crop received 182.3 mm and 167.8 mm of rainfall during the growing season of 2003 and 2004 respectively. The crop was sown on 7th March 2003 and 9th March 2004 and harvested on 18th July 2003 and 17th July 2004, respectively.

Results and discussion

Irrigation water influenced the crop growth significantly except 100-kernel weight. Irrigation applied three times at branching, peg development and pod development stages (I_3) recorded the significantly higher yield attributes *viz.*, pods/plant, branch/plant, kernel/pod than that of one irrigation (I_1). Application of one irrigation at branching stage only recorded the lowest yield components might be due to moisture stress during peg/pod development stages that hampered the proper growth and development of the crop (Table 1). Similar results have also been reported by Gulati and Lenka (1999).

All the yield components of groundnut were significantly influenced by Zinc application except 100-kernel weight. Maximum branches, pods/plant and kernel/pod were found under 20 kg Zn/ha. But 25 kg/ha recorded lower yield parameters probably due to toxic effect of higher dose of zinc. This caused reduction in growth and development of the crop. The result is in accordance with the findings of Majumder *et al.* (2001).

Irrigation application also influenced the yields of groundnut significantly. Pod, kernel and haulm yields were increased with increase in number of irrigation. Three irrigations applied at branching, peg development and pod development stages recorded maximum pod yield, Haulm

yield, harvest index and shelling percentage. Due to low yield parameters at one irrigation (I_1) yields of the crop were also minimum. The results were also in conformity with findings of Gulati and Lenka. (1999).

Similarly Zn @ 20 kg/ha recorded the highest pod yield and haulm yield of groundnut whereas no zinc application (control) recorded the lowest yield (Table 2). The results were in accordance with the findings of Chitdeshwari and Poongathan (2003) and Majumdar *et al.* (2001).

Harvest index and shelling percentage reached their maximum with the treatment of Zn @ 20 kg/ha (66.42 and 70.06% respectively) also reported by Yadav *et al.* (1991).

Irrigation levels did not effect the oil content of groundnut. However, three irrigations applied at branching, peg development and pod development stages (I_3) recorded significantly higher oil yield (620 kg/ha) than that of one and two irrigations. Zn application also influenced the oil content and oil yield of groundnut significantly.

Table 1 Effect of different levels of irrigation and zinc on yield attributes of groundnut (mean data)

Treatment	Branch/plant	Pods/plant	Kernel/pod	100-kernel weight (g)
Level of irrigation				
I_1	7	12	1.4	24.1
I_2	8	13	1.6	24.4
I_3	10	15	1.7	24.5
SEm±	0.4	0.4	0.04	0.3
CD (P=0.05)	1.1	1.1	0.11	NS
Levels of zinc				
Control (no Zn application)	8	12	1.5	24.3
Zn @ 15 kg/ha	8	13	1.5	24.3
Zn @ 20 kg/ha	9	14	1.6	24.1
Zn @ 25 kg/ha	8	13	1.5	24.1
SEm±	0.07	0.1	0.01	0.08
CD (P=0.05)	0.4	0.3	0.02	NS

Where, I_1 = Irrigation during branching; I_2 = Irrigation during branching and peg development; I_3 = Irrigation during branching, peg development and pod development stages

Table 2 Effect of different levels of irrigation and zinc application on yields and oil content of groundnut (mean data)

Treatment	Pod yield (q/ha)	Kernel yield (q/ha)	Shelling (%)	Haulm yield (kg/ha)	Harvest index (%)	Oil content (%)	Oil yield (kg/ha)
Level of irrigation							
I_1	13	9	67	2158	62.3	47.9	433
I_2	15	10	69	2334	65.2	48.2	504
I_3	18	13	71	2686	67.5	48.4	620
SEm±	0.4	0.32	0.3	485	0.5	0.2	135
CD (P=0.05)	1.3	0.98	0.91	147	1.4	NS	40
Levels of zinc							
Control (no Zn application)	15	10	68	2279	64.3	48.0	481
Zn @ 15 kg/ha	16	11	69	2388	65.2	48.2	519
Zn @ 20 kg/ha	17	12	70	2570	66.4	48.2	577
Zn @ 25 kg/ha	15	10	68	2322	64.3	48.1	493
SEm±	0.2	0.11	0.13	14	0.1	0.04	5.3
CD (P=0.05)	0.47	0.34	0.39	42	0.3	0.13	15.9

Where, I_1 = Irrigation during branching; I_2 = Irrigation during branching and peg development; I_3 = Irrigation during branching, peg development and pod development stages

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Drymatter production, yield and nutrient uptake of *rabi* soybean, *Glycine max* L. as influenced by residual fertility of different nitrogen management practices to *kharif* rice

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Abstract

A field experiment was conducted during *kharif* and *rabi*, 1999-2000 and 2000-01 on sandy clay loam soil at College Farm, College of Agriculture, Rajendranagar, Hyderabad to study the effect of conjunctive use of organic and inorganic sources of nitrogen to rice on growth and yield of soybean. Integrated nitrogen management practices to *kharif* rice have greatly influenced the growth, yield attributes, yield and nutrient uptake of soybean during both the years. Significantly higher drymatter production, NPK uptake, protein and seed yield of soybean were observed with application of 25% N through green leaf manure + 100% N through urea to rice as compared to other N management practices to rice. There was no significant difference between 25% N through FYM + 75% N through urea and 25% N through GLM + 75% N through urea in respect of drymatter and yield of soybean. Significantly lower protein yield was observed with 25% N through FYM and 75% N through urea.

Key words: Drymatter production (DMP), soybean, green leaf manure (GLM), Farm yard manure (FYM) and nutrient uptake

Introduction

Earlier recommendations for nutrient application to crops were made based on responses of individual crops rather than the cropping system as a whole. As a result, these recommendations often had turned to be uneconomical. Moreover, the nutrient requirements of a crop in a cropping system are influenced by the nature of preceding crop as well as the quantity of fertilizers applied (Biswas *et al.*, 1987). The influence of cropping system on the dynamics of soil fertility cannot be appraised precisely because of the contribution of native soil fertility, residual effect of previous crop and variations in nutrient management. The concept of "Integrated Nutrient Supply System" involving combination of organic and inorganic sources in cropping system has been known to improve soil health and provide maximum stability in production. Information on the residual effect of integrated nitrogen management practices to rice on succeeding crops and influence of previous crop on the succeeding crop in the cropping system with reference to productivity is lacking. Therefore, an investigation was carried out to find out the residual effect of different 'N' management practices to *kharif* rice on growth and yield of *rabi* soybean.

Material and methods

An experiment was conducted at College Farm, Rajendranagar, Hyderabad, on sandy clay loam soil during *kharif* and *rabi* seasons of 1999-2000 and 2000-01. The *kharif* rice crop was studied in a Randomized Block Design with four replications having five nitrogen management practices i.e., 25% N through farm yard manure (FYM) + 75% N through Urea, 25% N through FYM+100% N through urea, 25% N through green leaf manure - sunhemp (GLM)+75% N through urea, 25% N through GLM + 100%N through urea and 100% N through urea alone. In *rabi*, each of the *kharif* treatments were sub-divided into four plots to accommodate wheat, maize, soybean and groundnut crops. The experimental soil was low in available nitrogen (235 kg/ha) and phosphorous (20.2 kg/ha) and medium in available potassium (271 kg/ha) and low in organic carbon (0.6%) and pH 8.0 and EC 0.48 dS/m. The recommended dose of fertilizers to rice was 120 N + 60 P_2O_5 + 60 K_2O kg/ha and to soybean was 20 N + 80 P_2O_5 + 50 K_2O kg/ha. Uniform dose of 60 kg P_2O_5/ha and 60 kg K_2O/ha in the form of single super phosphate and muriate of potash was applied to all the *kharif* treatments, duly taking into consideration of the N, P and K content of the GLM and FYM. Green leaf manure (sunhemp) and farm yard manure were incorporated in

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soil, six days before transplanting of rice. The GLM was raised in a separate field, harvested at 45 DAS, transported and incorporated in the experimental field as per treatments. The experiment commenced from the *kharif* season of 1999-2000 and continued for four seasons on the same field without disturbing the layout. The soybean was sown with a spacing of 30 x 10 cm and variety was PK-472. The gross plot size was 5.4 x 3.6 m and net plot size was 4.6 x 1.8 m. N, P and K contents (%) in sunhemp and FYM were 2.52, 0.16, 0.51 and 0.64, 0.28, 0.58, respectively. The nutrient uptake was worked out in each crop by multiplying the nutrient concentration in the plant material at harvest with respective dry matter yield. The data recorded on growth, yield attributes, yield and nutrient uptake of soybean during study was analysed following the analysis of variance for Randomized Block Design. The seed yield of soybean was converted into protein yield on the basis of protein content of seed. Protein content in soybean seed was 43.2 g in 100 g of seed.

Results and discussion

Significantly higher DMP of soybean was observed with application of 25% N through GLM +100% N through urea to rice over all the other N management practices to rice, however, it was comparable with that of 25% N through FYM + 100% N through urea (Table 1). This may be attributed to substantial amount of residual nitrogen left by the treatment of 25% N through GLM along with 100% N through urea applied to preceding rice crop to succeeding soybean crop, which led to higher assimilatory surface area which helped in the development of efficient photo synthetic system with better availability of nutrients and moisture produced higher drymatter (Table 5). There was strong positive correlation between dry matter and NPK uptake (Table 4). Among organic sources, differential residual response with different sources can be attributed to their pattern of mineralisation and proportion of their substitution. These findings are in agreement with those of Patel and Puraji (2003).

The number of pods/plant of soybean observed with application of 25% N through GLM + 100% N through urea to rice was significantly superior to all the other treatments, however, it was comparable with that of 25% N through FYM + 100% N through urea applied to rice during 2000-2001. The increases in yield attributing characters are basically governed by vegetative growth. Higher dry matter production with former treatment resulted in better translocation of photosynthates to sink, thereby higher number of pods/plant. Application of 25% N through FYM + 75% N through urea to rice recorded comparable number of pods/plant as that of 25% N through GLM + 75% N through urea and significantly lower as compared to all other treatments (Table 1). There was strong positive correlation between dry weight at harvest and pods/plant (Table 4). The number of seeds/pod was not significantly influenced by nitrogen management practices to rice. Application of 25% N through GLM + 100 per cent N through urea to rice recorded comparable seed weight with that of application of 25% N through FYM + 100% N through urea to rice and significantly superior to all the other treatments. The 1000-seed weight recorded with the application of 25 % N through FYM + 75% N through urea to rice was comparable with that of 25% N through GLM + 75% N through urea during 2000-2001 and significantly lower as compared to all other treatments during both the years.

Seed and protein yield were significantly higher with application 25% N through GLM + 100% N through urea to rice which was significantly superior to rest of the treatments to rice (Table 2). The significant increase in yield was mainly attributed to efficient translocation of photosynthates from source to sink (Aruna and Reddy, 1999). Significantly lower seed and protein yield were recorded with application of 25% N through FYM + 75% N through urea to rice as compared to other treatments. Haulm yield and harvest index also followed the similar trend. Drymatter production, yield attributes and NPK uptake were favourable which improved the seed and protein yield. This type of trend also supported by strong positive correlation between seed yield and yield attributes (Table 4).

Nutrient uptake: Significantly higher nitrogen and potassium uptake were recorded with application of 25% N through GLM + 100% N through urea to rice as compared to all other N management practices to rice, but was comparable with that of 25% N through FYM + 100% N through urea and 100% N through urea applied to rice during 2000-2001 (Table 3). This might also be attributed to enhanced dry matter production in addition to higher availability of nitrogen and potassium in the soil (Table 5). Application of 25% N through GLM + 100% N through urea to rice recorded significantly higher phosphorus uptake as compared to rest of the treatments given to rice. Significantly lower phosphorus uptake was noticed with application of 25% N through FYM + 75% N through urea to rice over all other treatments. Green leaf manure on decomposition release organic acids, which enhance the availability of phosphorous and potassium by reducing their fixation, resulted in higher availability of P and K in soil, there by higher P and K uptake (Bouldin, 1987). Significantly lower uptake of nitrogen and potassium were observed with application of 25% N through FYM + 75% N through urea to rice as compared to all other treatments.

The above results clearly indicated that organic manures along with recommended doses of nitrogen can sustain the nutrient status of soil to produce reasonable residual effect. Application of 25% nitrogen GLM along with 100% nitrogen through urea to kharif rice exhibited significant residual effect on succeeding soybean by increasing yield (Table 5). Significant carry over effect due to substitution

of nitrogen with higher proportion of GLM or FYM to rice on the succeeding crops was also reported by Paulraj and Velayudham (1996).

It is inferred from the above investigation that significantly higher yield of soybean was recorded with recommended dose of fertilizers and application of 25% N through green leaf manure (sunhemp) + 100% N through urea to rice during *kharif*. This nitrogen management practices sustains the soil fertility under rice-soybean cropping system for better soil health and higher yield.

Table 1 Effect of various N management practices to *kharif* rice on DMP and yield attributes of *rabi* soybean

Treatments to rice	DMP at harvest		Pods/plant		Seed weight (g)	
	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
25% of N through FYM + 75% of N through urea	288	288	36.0	35.3	107	100
25% of N trough FYM + 100% of N through urea	350	352	44.0	44.0	123	120
25% of N through GLM + 75% of N through urea	308	308	36.7	36.0	113	104
25% of N through GLM + 100% of N through urea	384	383	45.7	45.0	125	121
100% of N through urea	348	342	42.7	42.6	119	112
SEm±	4.1	4.3	0.4	0.8	1.3	2.1
CD (P=0.05)	12.5	13.0	1.4	2.7	4.1	6.2

Table 2 Effect of various N management practices to *kharif* rice on seed, haulm and protein yield (kg/ha) and harvest index (%) of *rabi* soybean

Treatments to rice	Seed yield (kg/ha)		Haulm yield (kg/ha)		Protein yield (kg/ha)		Harvest index (%)	
	1999-00	2000-01	1999-00	2000-01	1999-00	2000-01	1999-00	2000-01
25% of N through FYM + 75% of N through urea	525	507	851	822	227	219	38.6	38.2
25% of N through FYM + 100% of N through urea	713	712	1066	1066	308	304	40.1	40.0
25% of N through GLM + 75% of N through urea	556	580	876	915	240	251	38.9	38.8
25% of N through GLM + 100% of N through urea	782	750	1143	1100	338	324	40.7	40.6
100% of N through urea	712	705	1064	1056	308	309	40.1	40.1
SEm±	13	18	17	32	3.0	3.4	0.3	0.3
CD (P=0.05)	39	54	51	97	9.2	10.3	0.9	1.0

Table 3 Effect of various N management practices to *kharif* rice on nitrogen, phosphorus and potassium uptake (kg/ha) by *rabi* soybean

Treatments to rice	Nitrogen		Phosphorus		Potassium	
	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
25% of N through FYM + 75% of N through urea	29.7	28.9	2.6	2.7	15.7	15.3
25% of N trough FYM + 100% of N through urea	41.7	41.5	4.1	3.9	22.1	21.9
25% of N through GLM + 75% of N through urea	31.7	33.1	2.9	3.1	17.0	17.9
25% of N through GLM + 100% of N through urea	45.3	43.7	4.6	4.5	24.1	23.3
100% of N through urea	41.0	41.1	3.8	4.1	21.4	21.6
SEm±	0.8	1.1	0.1	0.1	0.3	0.6
CD (P=0.05)	2.4	3.4	0.3	0.4	0.9	1.7

Table 4 Correlation coefficient between seed yield and growth, yield attributes and NPK uptake of soybean

Factor		'r' value	
		1999-2000	2000-2001
Seed yield Vs.	Dry weight at harvest	0.951**	0.898**
	Pods/plant	0.885**	0.878**
	Seed weight	0.624**	0.813**
	N uptake at harvest	0.994**	0.994**
	P uptake at harvest	0.987**	0.934**
	K uptake at harvest	0.988**	0.633**

** Significant at 1% level.

Table 5 Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of *kharif* rice (1999 and 2000) as influenced by various N management practices to rice

Treatments to rice	Available nitrogen		Available phosphorus		Available potassium	
	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
25% of N through FYM + 75% of N through urea	241	249	21.2	21.4	273	274
25% of N trough FYM + 100% of N through urea	251	258	21.9	22.0	276	276
25% of N through GLM + 75% of N through urea	245	250	21.5	21.7	274	274
25% of N through GLM + 100% of N through urea	257	264	22.7	22.8	277	277
100% of N through urea	238	243	20.7	20.4	272	274
SEm±	0.7	0.5	0.2	0.2	0.4	0.3
CD (P=0.05)	2.0	1.5	0.7	0.5	1.2	1.0
Initial value (kg/ha)	235		20.2		271	

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Studies on intercropping soybean, *Glycine max* (L.) Merill with sunflower, *Helianthus annuus* L. under rainfed conditions

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Abstract

A field experiment was conducted in *kharif* seasons of 2000, 2001 and 2002 to study the feasibility and productivity of intercropping soybean with sunflower at Main Agricultural Research Station, Dharwad (Karnataka). Intercropping soybean and sunflower in 3:1 row ratio with 100 % sunflower and 75 % soybean population resulted in significantly higher soybean equivalent yield, LER, net returns and B:C ratio over sole crops and other intercropping systems except soybean (75%) + sunflower(100%) intercropping at 4:2 row ratio. Though the intercropping system resulted in significant reduction in the yield of component crops as compared with sole crops, however, resulted in higher productivity and income/unit area.

Key words: Soybean, sunflower, intercropping, row ratio, equivalent yield

Introduction

The main concept of intercropping is to obtain increased total productivity/unit area and time, besides equitable and judicious utilization of available natural resources including labour. Higher productivity and returns in intercropping systems depend on the selection of compatible crops and their planting density and geometry (Shivaramu and Shivashankar, 1992). Soybean [*Glycine max* (L.) Merill] and sunflower [*Helianthus annuus* L.] are the important oilseed crops in Karnataka grown extensively during *kharif* season. Sunflower a widely spaced (60x20 cm) crop offers opportunity for growing short duration legumes like groundnut, mungbean, soybean etc. as intercrops (Shahbaz Ahmed and Rashid Ibrar, 1996). Therefore, the present investigation was aimed at exploring the possibility of intercropping soybean with sunflower under rainfed conditions in various row proportions and planting density.

Materials and methods

The field experiments were conducted during *kharif*, 2000, 2001 and 2002 at Main Agricultural Research Station, Dharwad (Karnataka) under rainfed conditions. The soil of the experimental site was medium deep black with 7.1 pH, having low available nitrogen (251 kg/ha), medium phosphorus (17.2 kg/ha) and medium potassium (349 kg/ha) contents. The experiment consisted of 10 treatment combinations of intercropping of soybean (cv.JS-335) with sunflower (cv.KBSH-1) in 1:1, 2:1, 3:1, 2:2 and 4:2 row proportions with 100 % sunflower population and 75 and 100% soybean population and compared with sole crops of soybean and sunflower. In all there were 12 treatments laid out in Randomized Block Design with three replications. In sunflower 100% and in soybean 75 and 100 % of recommended plant population were maintained as per treatment in intercropping systems by adjusting the plant spacing. The sole crops of sunflower and soybean were sown with a spacing of 60x20 cm and 30x10 cm, respectively. The recommended dose of fertilizer for soybean (40:80:25 kg NPK/ha) and sunflower (35:50:35 kg NPK/ha) in the form of Diammonium Phosphate, Urea and Muriate of Potash were applied as basal dose. In case of intercropping treatments, the fertilizers were applied independently as per their plant density. The rainfall received during the crop growing season of 2000, 2001 and 2002 was 270.8, 148.7 and 165.3 mm, respectively as against the normal rainfall of 303.8 mm.

Results and discussion

Soybean : The pooled results revealed that, sole crop of soybean recorded significantly higher seed yield compared to intercropping treatments (Table 1). Intercropping soybean with sunflower resulted in significant reduction of soybean yield during all the years of study, the extent of reduction was highest in 1:1 and least in 3:1 row ratios. The decrease in the yield of soybean in intercropping system was mainly due to greater competition from sunflower for moisture, nutrients, light and space. Srivastava *et al.* (1980) also reported reduction in yield of intercropped soybean due to shading effect of sunflower. Further, keeping 100 % soybean population in the system recorded slightly higher soybean yield compared to 75% population.

Sunflower : Significantly higher seed yield of sunflower was obtained in the sole crop as compared to all the intercrops, which hampered its production. The magnitude of reduction due to intercropping was less in 1:1 row ratio followed by 2:2 and 4:2 row ratios. The reduction in the yield of sunflower in intercropped treatments was mainly

due to loss in area (rows) for the crop which was occupied by soybean and competition between closely spaced plants when 100 % sunflower population was adjusted within the row. The effect of population of soybean on sunflower yield was not much as the yield levels of 75 and 100 % populations were comparable. These results are in agreement with the findings of Shivaramu and Shivashankar (1992).

Soybean equivalent yield: Pooled data of three years showed that, intercropping soybean with sunflower at 3:1 row ratio with 75 % soybean population produced higher soybean equivalent yield, land equivalent ratio, net income and B:C ratio (Table 2). Significantly higher soybean equivalent yield was obtained from intercropping of soybean and sunflower in 3:1 row ratio with 75 % soybean population except sunflower + soybean intercropping at same row ratio with 100 % soybean population and 4:2 row ratio with 75% plant density of soybean. The higher equivalent yield with these treatments was mainly due to higher yield of component crops in the system. Both the intercrops performed better in paired rows or when sunflower was spaced wider.

Land equivalent ratio: The complementarity of soybean-sunflower intercropping was also seen from land equivalent ratio. It was highest in 3:1 row ratio with 75 % soybean plant population (1.36) followed by same row ratio with 100 % soybean population (1.32). Sarkar and Chakraborthy (1999) also reported higher equivalent yield and LER when sunflower was intercropped with greengram. Similarly, Koppalkar and Sheelavantar (1990) reported higher equivalent yield and LER when groundnut was intercropped with sunflower compared to their respective sole crops.

Economics: Net returns and benefit cost ratios were also higher with intercropping systems compared to sole crops. Intercropping soybean + sunflower in 3:1 and 4:2 row ratio with 75% soybean population gave higher net return and benefit:cost ratio (2.04 and 1.98, respectively) over other intercropping and sole cropping treatments. The higher net income and benefit, cost ratio with these treatments was due to higher complimentarity between these component crops, which produced higher combined yield, and net returns. These results are in conformity with the findings of Shivaramu and Shivashankar (1992) and Shahbaz Ahmad and Rashid Ibrar (1996).

It was concluded that intercropping soybean and sunflower in 3:1 row proportion with 75 % soybean population was more productive and remunerative than sole crop of soybean or sunflower under rainfed conditions of northern transitional zone of Karnataka.

Table 1 Yield of Soybean and Sunflower and Soybean equivalent yield as influenced by intercropping of soybean and sunflower

Treatment	Sunflower seed yield (kg/ha)				Soybean seed yield (kg/ha)				Soybean equivalent yield (kg/ha)			
	2000-01	2001-02	2002-03	Pooled	2000-01	2001-02	2002-03	Pooled	2000-01	2001-02	2002-03	Pooled
Soybean 100%+Sunflower 100% (1:1)	1235	1059	1113	1136	309	260	278	282	1980	1562	1614	1718
Soybean 75%+Sunflower 100% (1:1)	1298	1091	1152	1180	272	244	256	257	2028	1586	1638	1751
Soybean 100%+Sunflower 100% (2:1)	1094	912	968	991	676	448	474	533	2112	1570	1635	1772
Soybean 75%+Sunflower 100% (2:1)	1124	962	1016	1034	634	426	447	502	2156	1609	1667	1810
Soybean 100%+Sunflower 100% (3:1)	1031	853	905	930	971	727	763	820	2365	1777	1849	1997
Soybean 75%+Sunflower 100% (3:1)	1084	892	951	976	948	701	736	795	2415	1799	1890	2035
Soybean 100%+Sunflower 100% (2:2)	1202	1024	1074	1100	425	319	345	363	2052	1578	1634	1755
Soybean 75%+Sunflower 100% (2:2)	1244	1073	1125	1147	403	306	321	343	2086	1625	1671	1794
Soybean 100%+Sunflower 100% (4:1)	1066	947	1011	1008	794	580	613	663	2236	1744	1826	1936
Soybean 75%+Sunflower 100% (4:1)	1109	927	1046	1027	760	562	590	636	2260	1785	1869	1971
Sole sunflower (60cm x 20 cm)	1355	1175	1218	1249	-	-	-	-	1833	1445	1462	1580
Sole soybean (30 cm x 10 cm)	-	-	-	-	1751	1232	1284	1422	1751	1235	1284	1422
SEm±	103.5	31.6	16.7	22.4	33.5	19.4	13.9	13.7	86.4	25.7	23.4	31.1
CD (P=0.05)	305.5	93.4	49.1	61.7	98.9	57.1	40.8	37.7	254.8	75.8	68.3	85.7

Table 2 Land equivalent ratio, net returns and benefit : cost ratio as influenced by intercropping of soybean and sunflower

Treatment	Land equivalent ratio				Net returns (Rs/ha) (Pooled)	Benefit Cost ratio (Pooled)
	2000-01	2001-02	2002-03	Pooled		
Soybean 100%+Sunflower 100% (1:1)	1.09	1.11	1.13	1.11	6820	1.61
Soybean 75%+Sunflower 100% (1:1)	1.11	1.13	1.15	1.13	7927	1.76
Soybean 100%+Sunflower 100% (2:1)	1.17	1.29	1.16	1.21	7316	1.65
Soybean 75%+Sunflower 100% (2:1)	1.40	1.22	1.18	1.27	8491	1.81
Soybean 100%+Sunflower 100% (3:1)	1.31	1.32	1.34	1.32	9683	1.86
Soybean 75%+Sunflower 100% (3:1)	1.38	1.33	1.37	1.36	10853	2.04
Soybean 100%+Sunflower 100% (2:2)	1.13	1.13	1.15	1.14	7168	1.64
Soybean 75%+Sunflower 100% (2:2)	1.15	1.16	1.17	1.16	8371	1.80
Soybean 100%+Sunflower 100% (4:1)	1.24	1.28	1.31	1.28	9101	1.81
Soybean 75%+Sunflower 100% (4:1)	1.26	1.30	1.34	1.30	10273	1.98
Sole sunflower (60cm x 20 cm)	1.00	1.00	1.00	1.00	8583	2.02
Sole soybean (30 cm x 10 cm)	1.00	1.00	1.00	1.00	6828	1.82

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Physiological response of mustard, *Brassica juncea* (L.) Czern & Coss to residual and direct effects of integrated phosphorus nutrition

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Abstract

A field study was conducted during 2000-01 and 2001-02 at Indira Gandhi Agricultural University, Raipur to study the residual effect of integrated phosphorus nutrition to *kharif* rice on mustard cv. Pusa bold. The plant height, number of primary branches, dry matter production, LAI, light interception by crop canopy and seed yield of mustard under residual effect of 100% RDP blended with cow dung +PSB was found to be significantly higher followed by 75% RDP blended with cow dung + PSB. The residual effect of 75 or 100% RDP blended with cow dung + PSB produced 3.3 and 14.7% higher seed than 100% RDP, respectively. Direct application of 100% RDP blended with cow dung also excelled in these characters and recorded 10.3% higher seed yield over 100% RDP. The interaction effect of 100% RDP blended with cow dung + PSB applied in *kharif* and 100% RDP blended with cow dung in *rabi* produced significantly higher seed yield in comparison to other treatment combinations.

Key words: Blending, cow dung, PSB, light interception, yield, mustard

Introduction

Crop plants use only a small fraction of phosphatic fertilizers containing water soluble P, while remaining portion of applied phosphorus becomes fixed in the soil or rendered unavailable to crops (Prakash *et al.*, 1997). Hence phosphate management strategies adopted in one crop influence the phosphorus needs of the succeeding crops. Moreover, in high rainfall regions of eastern India among various rice-based cropping systems, rice-mustard is an economically viable cropping system, where single super phosphate is a widely used source of phosphorus. Therefore, there is need to study the residual as well as direct effect of integrated phosphorus nutrition on mustard crop grown after rice.

Materials and methods

The experiment was conducted during *kharif* seasons of 2000 and 2001 at the Instructional farm of Indira Gandhi Agricultural University, Raipur. The soil of experimental field was sandy loam in texture, neutral in reaction (pH 7.3), low in organic carbon (0.44 %) and available N (203.0 kg/ha), medium in available P (12.8 kg/ha) and high in available K (346.5 kg/ha). Ten treatments *viz.*, no P, 50% recommended P (50% RDP), 50% RDP blended with cow dung + phosphorus solubilizing bacteria (PSB), 50% RDP blended with poultry manure + PSB, 75 % RDP, 75% RDP blended with cow dung + PSB, 75% RDP blended with poultry manure + PSB, 100% RDP, 100% RDP blended with cow dung +PSB, 100% RDP blended with poultry manure + PSB were applied to rice cv. Mahamaya (125-130 days) during *kharif* seasons in a Randomized Block Design with three replications. In the succeeding *rabi* seasons, the residual effect of kharif treatments (main plot treatments) and direct effect of six P management treatments *viz.*, no phosphorus, PSB, 50 and 100 % RDP with or without blending with cow dung (sub-plot treatments) were studied on mustard cv. Pusa bold in Split Plot Design with three replications.

In rice, N and K were applied uniformly at 100 kg and 40 kg/ha as urea and MOP, respectively but P application was done as per the treatment. The recommended dose of P was 60 kg/ha as single super phosphate. Phosphorus *solubilizing bacteria* @ 2.5 kg/ha was first mixed with cow dung @ 3 t/ha (fresh cow dung decomposed for 14 days) or 1.5 t/ha of poultry manure and then blended with the required quantity of SSP. This was incubated for 48 hours prior to application at transplanting. In mustard, 50 and 100 % RDP as SSP was blended with cow dung and applied basally (recommended dose was 40 kg P_2O_5/ha). The blending technique followed was similar to *kharif* treatments. A common dose of N and K were applied basally at 80 kg N and 40 kg K_2O/ha through urea and muriate of potash, respectively. The cow dung contained 24.2% C, 0.4% N, 0.25% P, 0.37% K, 83.1% moisture and poultry manure contained 26.5% C, 1.6% N, 0.66% P, 1.0% K, 14.6% moisture. Growth parameters such as plant height, number of branches, light interception by crop canopy, dry matter accumulation, days to 50 % flowering as well as seed and stalk yields well as seed and stalk yields were recorded. Physiological parameters like LAI, leaf area duration (LAD), thermal requirement for flowering (growing degree days) and harvest index (HI) were computed.

LAI of the five uprooted plants was measured by Licor-300 leaf area meter and their average was taken to find out the

Leaf area/plant: The leaf area was calculated at 45 and 90 DAS. LAI for each stage was computed as:

$$LAI = \frac{\text{Total leaf area of the plant}}{\text{Total ground area under the plant}}$$

$$LAD \text{ (days)} = LAI \times M$$

Where

$$LAI = (LAI_{45} + LAI_{90})/2$$

LAI_{45} and LAI_{90} are the LAI at 45 and 90 DAS, respectively
M = Time interval in days between the two successive LAI observations

Light interception (LI) by mustard crop canopy at 75 DAS was worked out by observing the light intensity by Lux meter. Light interception was computed as:

$$LI(\%) = \frac{\text{Light intensity at the top-average light intensity (mid+ground)}}{\text{Light intensity at the top of the plant}} \times 100$$

Harvest index was calculated as:

$$HI(\%) = \frac{\text{Grain yields}}{\text{Total biological yield}} \times 100$$

Growth degree-days was calculated by simple arithmetic accumulation of daily mean temperatures above a base temperature. The base temperature for mustard is 5°C (Singh *et al.* 1995).

Results and discussion

Growth parameters: Growth parameters of mustard under residual effect of 100% RDP blended with cow dung + PSB recorded the highest values and were comparable to 75 or 100 % RDP blended with poultry manure + PSB and 100% RDP in plant height, to 75% RDP blended with cow dung + PSB in case of number of primary branches and to 75 % RDP blended with cow dung + PSB in case dry matter production (Table 1). Significantly higher growth response of mustard to residual effect of integrated P nutrition might be attributed to the favourable modifications in soil physico-chemical properties for retention of nutrients, which became available for the growth and development of the succeeding crop (Sharma *et al.*, 1999). In direct application, 100 % RDP blended with cow dung excelled in all these parameters which was on par to 100% RDP and 50% RDP blended with cow dung for plant height, but was not comparable with other treatments for rest of the characters. The protective action of organic manures in reducing the dissolution rate and surface area of contact with soil particles might have favoured more available P for plant growth (Prakash *et al.*, 1997) and release of organic anions and solubilization of Ca-P by decomposition products of organic matter (Brar *et al.*, 1999).

The LAI at 45 and 90 DAS, LAD (45-90 DAS) and light interception through mustard crop canopy revealed significant superiority of residual effect of 100% RDP blended with cow dung + PSB. This treatment was *comparable to similar level of P either applied alone* or blended with poultry manure +PSB for LAI and LAD. In direct effect also 100% RDP blended with cow dung recorded significantly higher LAI, LAD and maximum light interception as compared to the rest of the treatments, which followed a declining trend with reduced level of P. Increased N uptake resulting out of increased supply of P due to synergistic effect (Prakash *et al.*, 2000) might have favoured cell multiplication and resulted in higher LAI, LAD and consequently more of light interception. Similar observations were also reported by Bhagat and Soni (2000).

Days to flowering and thermal requirement: Days to 50 % flowering under residual effect of 100% RDP blended with cow dung + PSB was significantly delayed, which got hastened with lower doses of P. However, 75 or 100% RDP blended with cow dung or poultry manure + PSB and 100% RDP took similar duration (Table 2). In direct effect, the earliest flowering was noted with no phosphorus which prolonged with increasing P levels and significantly highest number of days was noted under 100% RDP blended with cow dung. This corroborates earlier findings of Prakash *et al.* (2000) who observed delayed flowering with higher levels of fertilizer. Accumulation of growing degree days (GDD) for flowering of mustard due to the residual and direct effects of various integrated P nutrition also exhibited a similar trend as that of days to 50% flowering. This is obviously true because higher the number of days, more will be the accumulated heat.

Yield and HI: Seed yield of mustard was significantly highest under residual effect of 100% RDP blended with cow dung + PSB. In case of straw yield, residual effect of 100% RDP blended with cow dung + PSB was significantly superior to rest of the treatments except 100 % RDP blended with poultry manure + PSB. The residual effect of 75 or 100% RDP blended with cow dung +PSB produced 3.3 and 14.7% higher seed than 100% RDP, respectively. There was no significant residual effect of treatments on HI. The directly applied integrated P to mustard produced the highest seed and straw yields under 100 % RDP blended with cow dung which was significantly superior to any other treatments. This treatment produced 10.3% higher seed yield over 100% RDP. However, direct application of 50% RDP blended with cow dung was at par *with 100% RDP. Higher values of growth parameters* under these treatments possibly resulted in more of yield attributes and yield. Enhanced growth and branching might have provided greater potential sites for siliqua formation and as a result enhanced yield (Kumar *et al.*, 2000).

The interaction of residual and directly applied integrated P significantly influenced the seed yield during the second year only (Table 3). The interaction of residual effect of 100% RDP blended with cow dung + PSB and direct effect

of 100% RDP blended with cow dung produced significantly higher seed yield of mustard compared to other inter actions. This combination was closely followed by the interaction effect of 75% RDP blended with cow dung + PSB with direct application of 100% RDP blended with cow dung. The interaction effect was not significant on HI indicating least role of P in influencing source - sink relationship.

Table 1 Effect of integrated P nutrition on plant height, number of primary branches, dry matter production, leaf area index and leaf area duration of mustard (pooled for 2 years)

Treatment	Plant height at harvest (cm)	Primary branches/ plant at harvest	Drymatter accumulation at 90 DAS (g/plant)	Leaf area index		Leaf area duration (45-90 DAS) days
				45 DAS	90 DAS	
Residual effect						
No phosphorus	146	4	16.15	3.22	1.18	99.1
50% RDP	151	5	17.60	3.48	1.31	107.7
50% RDP blended with cow dung +PSB	154	5	21.41	3.68	1.33	112.6
50% RDP blended with poultry manure + PSB	155	5	20.89	3.76	1.37	115.4
75% RDP	156	5	19.42	3.96	1.47	122.0
75% RDP blended with cow dung + PSB	159	6	22.53	4.10	1.53	126.6
75% RDP blended with poultry manure + PSB	160	6	21.85	4.17	1.54	128.5
100 % RDP	160	6	21.23	4.36	1.56	133.2
100% RDP blended with cow dung + PSB	163	6	23.65	4.43	1.63	136.3
100% RDP blended with poultry manure + PSB	163	6	22.42	4.38	1.60	134.5
SEm ±	1.7	0.1	0.50	0.02	0.03	1.0
CD (P = 0.05)	5.0	0.2	1.48	0.06	0.09	2.9
Direct effect						
No phosphorus	149	4	14.84	3.47	1.28	106.9
PSB	151	4	15.90	3.58	1.31	110.0
50% RDP	155	5	19.58	3.92	1.44	120.6
50% RDP blended with cow dung	160	6	23.36	4.14	1.53	127.4
100 % RDP	162	6	23.84	4.22	1.55	129.6
100% RDP blended with cow dung	164	6	26.18	4.39	1.62	135.1
SEm ±	1.6	0.1	0.33	0.02	0.02	0.5
CD (P = 0.05)	4.4	0.2	0.92	0.04	0.05	1.5

Table 2 Effect of integrated P nutrition on light interception, days to flowering, thermal requirement, yields and harvest index of mustard (pooled for 2 years)

Treatment	Light interception (75 DAS)(%)	Days to 50% flowering (days)	Thermal requirement for flowering (growing degree days)	Seed yield (q/ha)	Stalk yield (q/ha)	Harvest index (%)
Residual effect						
No phosphorus	56.1	42.5	619	9.52	29.77	24.24
50% RDP	60.6	44.6	645	10.88	31.98	25.35
50% RDP blended with cow dung +PSB	64.0	45.3	654	12.77	36.83	25.75
50% RDP blended with poultry manure + PSB	65.5	45.3	654	12.84	38.03	25.34
75% RDP	69.4	45.3	654	12.01	35.39	25.48
75% RDP blended with cow dung + PSB	71.9	49.0	700	14.05	40.83	25.64
75% RDP blended with poultry manure + PSB	71.1	47.3	680	13.47	39.74	25.41
100 % RDP	75.4	47.0	676	13.04	38.64	25.30
100% RDP blended with cow dung + PSB	78.4	50.0	714	14.96	42.63	26.07
100% RDP blended with poultry manure + PSB	77.2	49.5	706	13.91	40.65	25.54
SEm ±	0.4	1.0	4	0.16	0.92	0.52
CD (P = 0.05)	1.1	3.1	13	0.46	2.73	NS
Direct effect						
No phosphorus	61.0	43.8	636	9.23	26.87	25.55
PSB	62.5	44.3	642	9.98	28.74	25.77
50% RDP	68.0	45.7	659	12.07	35.51	25.38
50% RDP blended with cow dung	73.1	46.9	674	14.51	42.48	25.50
100 % RDP	73.6	48.0	688	14.61	43.47	25.06
100% RDP blended with cow dung	75.6	50.8	724	16.11	47.63	25.22
SEm ±	0.1	0.4	2	0.19	0.47	0.33
CD (P = 0.05)	0.3	1.1	5	0.53	1.31	NS

Table 3 Interaction effect of residual and directly applied integrated P nutrition on seed yield of mustard during 2001-02

Treatment	Direct effect						
	No phosphorus	PSB	50 % RDP	50 % RDP blended with cow dung	100 % RDP	100 % RDP blended with cow dung	Mean
Residual effect							
No phosphorus	6.59	7.53	8.87	10.74	10.89	11.77	9.40
50% RDP	7.77	8.58	10.38	12.63	12.74	13.89	11.00
50% RDP blended with cow dung +PSB	9.08	10.02	12.13	14.75	14.89	16.22	12.85
50% RDP blended with poultry manure + PSB	9.09	9.98	12.08	14.65	14.83	16.16	12.80
75% RDP	8.46	9.34	11.31	13.76	13.88	15.13	11.98
75% RDP blended with cow dung + PSB	9.91	10.78	13.18	16.08	16.17	17.63	13.96
75% RDP blended with poultry manure + PSB	9.32	10.29	12.46	15.16	15.29	16.67	13.20
100 % RDP	9.07	10.01	12.12	14.64	14.87	16.31	12.84
100% RDP blended with cow dung + PSB	10.32	11.40	13.92	17.04	17.09	18.72	14.75
100% RDP blended with poultry manure + PSB	9.90	10.87	13.16	16.06	16.15	17.50	13.94
Mean	8.95	9.88	11.96	14.55	14.68	16.00	
For comparing means of residual effects at the same level of direct effect							
SEm ±	0.74						
CD (P = 0.05)	2.07						
For comparing means of direct effects at the same or different level of residual effect							
SEm ±	0.72						
CD (P = 0.05)	2.05						

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Comparison of phenological development and growth dynamics of oilseed *Brassica* species under different growing environments

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Abstract

Field experiments were conducted at Ludhiana to compare phenology and growth dynamics of three *Brassica* species *viz., Brassica juncea* cv. RL-1359, *Brassica napus* cv. PGSH-51 and *Brassica carinata* cv. PC-5 under three dates of sowing (D_1 : Early October; D_2 : Late October and D_3 : Mid November) and three irrigation regimes (I_0 : Pre-sowing irrigation alone; I_1 : Pre-sowing irrigation + irrigation at 30 DAS; I_2 : Pre-sowing irrigation + irrigation at 30 DAS + Irrigation at flowering stage) during *rabi* 2001-02 and 2002-03. Crop phenological development stages, physiological maturity as well as crop growth rate, yield and yield attributes were recorded. Amongst the three *Brassica* species, *B. juncea* completed its life cycle under D_1, D_2 and D_3 dates of sowing in 160, 149 and 140 days; *B. napus* in 181, 171 and 153 days and *B. carinata* in 187, 171 and 161 days, respectively. Peak crop growth rate of 31.5, 13.8 and 9.6 g/m^2/day was observed for *B. juncea, B. carinata* and *B. napus*, respectively for early October sown (D_1) crop. The yield and yield attributes of brassica species were also significantly influenced by dates of sowing and irrigation regimes. Amongst the three species, *B. juncea* produced higher yield attributes followed by *B. carinata* and *B. napus* in decreasing order.

Key words: *Brassica juncea, Brassica napus, Brassica carinata,* crop growth rate, phenology, yield attributes, seed yield

Introduction

Brassica juncea is the most commonly cultivated species in rapeseed and mustard group of crops in Punjab and is the main *rabi* (winter) oilseed in the state. *Brassica napus* (Gobhi sarson) is an important species and being a rich source of edible oil its popularity has increased tremendously.

Prevailing weather conditions have profound effect on phenological development and yield of *Brassica* cultivars. Likewise, crop growth rate (CGR) for mustard also varies at different growth intervals (Nanda *et al.*, 1994; Kar and Chakravarthy, 2000; Hundal *et al.*, 2004). Response of *Brassica* species is therefore largely governed by changes in growing environment such as date of sowing and water availability. Therefore, the present study was undertaken to compare phenological development and crop growth rates of oilseed brassica species under varied environments of dates of sowing and irrigation regimes.

Materials and methods

Field experiments were conducted during *rabi*, 2001-02 and 2002-03 to compare growth dynamics of three *Brassica* species, *viz., B. juncea* cv. RL-1359; *B. napus* cv. PGSH-51 and *B. carinata* cv. PC-5 under three dates of sowing [D_1 : Early (9-10-2001 and 8-10-2002); D_2 : Optimum (29.10.2001 and 28.10.2002); D_3 : Late (13.11.2001 and 18.11.2002)], at three irrigation regimes (I0 :Pre-sowing irrigation alone; I_1 : Pre-sowing irrigation + Irrigation at 30 DAS; I_2 : Pre-sowing irrigation + Irrigation at 30 DAS + Irrigation at flowering stage) at Ludhiana, India (30° 54' N latitude and 75° 48' E longitude, 247 m above mean sea level).

The experiment was conducted in Split Plot Design (Main plot - date of sowing Split plot - *Brassica* species, Split-Split Plot - irrigation regimes) with four replications. The crop received 100 kg N/ha in the form of urea and 30 kg P_2O_5/ha in the form of single super phosphate during both the crop seasons. At sowing, one half of nitrogen and all P_2O_5 was applied as basal dose. The remaining half dose of nitrogen was given at first irrigation. The crop was applied irrigation as per irrigation schedule of the irrigation treatments.

Observations on crop phenological development with respect to seedling emergence, initiation and 50% flowering, initiation and 50% pod formation, initiation and 50% pod filling and physiological maturity were recorded. Total drymatter accumulation was obtained from plant samples collected at 15 days interval. Crop Growth Rate (CGR) was computed as under:

$$\text{Crop Growth Rate (g/m}^2\text{/day)} = \frac{DW_2 - DW_1}{T_1 - T_1}$$

Where, DW_2 and DW_1 are the total above ground drymatter of the crop from unit area (g/m^2) observed on days T_2 and T_1, respectively, during the time interval.

At the time of harvest of crop, data on yield and yield

attributes with respect to number of primary and secondary branches, number of pods, 1000-seed weight, pod yield, seed yield, straw yield and biomass yield were collected.

Results and discussion

Crop phenology: The emergence of seedlings for all *Brassica* species started on 3rd, 4th and 55th day during *rabi*, 2001-02 and on 4th, 5th and 6th day during *rabi*, 2002-03 under D_1, D_2 and D_3 dates of sowing, respectively (Table 1).

During both the crop seasons, flowering under D_1, D_2 ar D_3 dates of sowing treatments started respectively aft 35-40, 38-39 and 63 DAS in *B. juncea*; 88-91, 89-91 ar 93-95 DAS in *B. napus* and 62-71, 73-84 and 85-76 DA in *B. carinata*. The duration from 50% flowering to 50 pod formation during the two crop seasons under D_1, D_2 and D_3 dates of sowing was 5-10, 6-7, 8-15 days, in *juncea*; 7-12, 10-13 and 2-7 days, in *B. napus*; and 25-2 20-22 and 17-21 days in *B. carinata*, respectively.

Table 1 Phenological calender of *Brassica* species under different dates of sowing during *rabi* 2001-02 and *rabi*, 2002-03

Phenological stage	Occurrence of phenological stage (Julian day*)					
	Rabi, 2001-02			*Rabi*, 2002-03		
	D_1	D_2	D_3	D_1	D_2	D_3
***Brassica juncea* (Cv. RL-1359)**						
Emergence	285 (3)	306 (4)	322 (5)	285 (4)	306 (5)	328 (6)
Initiation flowering	317 (35)	340 (38)	15 (63)	321 (40)	240 (39)	20 (63)
50% flowering	329 (47)	351 (49)	17 (65)	331 (50)	350 (49)	28 (71)
Initiation pod formation	336 (54)	353 (51)	20 (68)	333 (52)	351 (50)	31 (74)
50% pod formation	339 (57)	359 (57)	32 (80)	336 (55)	357 (56)	36 (79)
Initiation pod filling	344 (62)	5 (68)	36 (84)	340 (59)	6 (70)	41 (84)
50% pod filling	349 (67)	10 (73)	41 (89)	344 (63)	11 (75)	46 (89)
Physiological maturity	73 (156)	82 (145)	91 (139)	79 (163)	89 (153)	99 (142)
***Brassica napus* (cv. PGSH-51)**						
Emergence	285 (3)	306 (4)	322 (5)	285 (4)	306 (5)	328 (6)
Initiation flowering	5 (88)	26 (89)	45 (93)	7 (91)	27 (91)	42 (85)
50% flowering	12 (95)	35 (98)	52 (100)	14 (98)	36 (100)	49 (92)
Initiation pod formation	24 (107)	45 (108)	60 (108)	21 (105)	43 (107)	55 (98)
50% pod formation	29 (112)	48 (111)	64 (112)	26 (110)	46 (110)	60 (113)
Initiation pod filling	34 (117)	53 (116)	69 (117)	36 (120)	51 (115)	65 (118)
50% pod filling	39 (122)	53 (116)	73 (121)	42 (126)	55 (119)	68 (121)
Physiological maturity	97 (180)	108 (171)	106 (154)	97 (181)	106 (170)	109 (152)
***Brassica carinata* (Cv. PC-5)**						
Emergence	285 (3)	306 (4)	322 (5)	285 (4)	306 (5)	328 (6)
Initiation flowering	344 (62)	10 (73)	37 (85)	351 (71)	20 (84)	33 (76)
50% flowering	356 (74)	19 (82)	41 (89)	360 (79)	25 (89)	47 (90)
Initiation pod formation	12 (95)	36 (99)	55 (103)	14 (98)	43 (107)	57 (100)
50% pod formation	15 (98)	39 (102)	62 (110)	21 (105)	47 (111)	64 (107)
Initiation pod filling	25 (108)	47 (110)	66 (114)	31 (115)	56 (120)	72 (115)
50% pod filling	31 (114)	53 (116)	70 (117)	38 (122)	60 (124)	76 (119)
Physiological maturity	101 (184)	107 (170)	112 (160)	105 (189)	108 (172)	118 (161)

* Day of the year; *D_1 : 9-10-2001 and 9-10-2002; D_2 : 29-10-2001 and 28-10-2002; D_3 : 13-11-2001 and 18-11-2002
Figures in parenthesis indicate days after sowing

The pod filling duration was delayed by delay in sowing from 1st week of October to 2nd week of November by 39-46 days in *B. juncea;* 26-27 days in *B. napus;* and 33-34 days in *B. carinata.* However, as the vegetative phase of *B. carinata* and *B. napus* was prolonged by 30-50 days as compared to *B. juncea*, so pod filling duration was more prolonged in *B. juncea*.

Amongst the three *Brassica* species, *B. juncea* completed its life cycle in 156 to 139 days (*rabi*, 2001-02) and 163 to 142 days (*rabi*, 2002-03); *B. napus* in 180 to 154 days (*rabi*, 2001-02) and 181 to 152 days (*rabi*, 2002-03) and *B. carinata* in 184 to 160 days (*rabi*, 2001-02) and 189 to 161 days (*rabi*, 2002-03) under D_1, D_2 and D_3 dates of sowing. Similar results under Ludhiana conditions were also reported by Nigam (2004) in *B. juncea*, Gill (2002) in *B. carinata*, Singh (1999) in *B. napus* species. Similar results for different *Brassica* species were also reported by Singh *et al.* (1993) and Nanda *et al.* (1994).

Crop Growth Rate (CGR): Crop Growth Rate (CGR) for three *Brassica* species under three irrigation regimes for two crop seasons over growth intervals from emergence to 35 days after sowing (DAS), 35 to 65 DAS, 65 to 95 DAS, 95 to 125 DAS and 125 to 155 DAS are presented in Table 2, 3 and 4 for D_1, D_2 and D_3 dates of sowing, respectively.

In general, amongst the three species, higher CGR were observed in *B. juncea* followed by *B. carinata* and *B. napus* which could be ascribed to differences in their growth habits. The maximum CGR of 31.5 g/m²/day for *B. juncea* between 95 to 125 DAS under I_2 irrigation was observed for the crop sown during early October, 2001 (Table 2) whereas peak CGR for *B. napus* and *B. carinata* was observed between 125 to 155 DAS. For crop sown during late October, peak CGR occurred between 65 to 125 DAS for *B. juncea*, between 95 to 125 DAS for both *B. napus* and *B. carinata* (Table 3), whereas for crop sown during mid November, peak CGR occurred between 65 to 95 DAS for *B. juncea*, 95 to 125 DAS for both *B. napus* and *B. carinata* (Table 4). In general, CGR decreased with delay in sowing for all the three species. Similar results have been reported for mustard cultivars B.O.-54 and Pusa bold and Toria-T9 by Kar and Chakravarty (2000) under New Delhi conditions and for mustard cultivars Bio-902 and Pusa Bold by Hundal *et al.* (2004) under Ludhiana conditions.

Yield attributes and yield: The three *Brassica* species sown during early October showed significantly higher yield attributes as compared to late sown crop (Table 5). Similar results on sowing dates of three mustard cultivars (RH 30, Luxmi and Varuna) were reported at Hisar and for mustard cultivars Bio-902 and Pusa Bold at Ludhiana (Hundal *et al.*, 2004).

Table 2 Comparison of crop growth rates (g/m²/day) of three *Brassica* species sown during early October (D_1) under different irrigation regimes and two crop seasons

Days after sowing	*Brassica juncea* cv. RL-1359			*Brassica napus* cv. PGSH-51			*Brassica carinata* cv. PC-5		
	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2
				Crop season = 2001-02					
35	0.20	0.21	0.55	0.19	0.52	0.52	0.28	0.29	0.34
65	4.84	4.99	5.42	5.92	6.67	6.67	5.68	6.07	2.88
95	10.02	20.63	18.61	6.10	4.10	4.10	7.11	6.31	6.09
125	20.31	23.35	31.49	5.97	9.00	9.62	5.23	4.28	2.49
155	2.23	-	2.50	3.42	6.54	5.86	8.87	11.85	13.79
				Crop season = 2002-03					
35	0.29	0.31	0.31	0.39	0.39	0.53	0.31	0.39	0.49
65	3.13	3.43	3.14	4.44	6.64	6.01	3.76	5.21	4.37
95	10.13	9.74	12.13	5.32	5.18	3.61	7.01	4.83	6.99
125	16.36	16.29	19.22	4.02	2.82	4.05	6.15	7.79	3.62
155	12.01	8.07	4.39	7.24	9.54	8.70	9.53	9.49	7.88

Table 3 Comparison of crop growth rates (g/m²/day) of three *Brassica* species sown during late October (D_2) under different irrigation regimes and two crop seasons

Days after sowing	*Brassica juncea* cv. RL-1359			*Brassica napus* cv. PGSH-51			*Brassica carinata* cv. PC-5		
	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2
				Crop season = 2001-02					
35	0.12	0.16	0.19	0.20	0.26	0.33	0.14	0.14	0.17
65	1.77	4.45	4.92	2.89	3.85	4.02	1.89	1.39	2.52
95	9.82	11.43	11.59	8.13	8.10	9.01	9.67	9.73	10.53
125	8.71	6.27	3.60	8.54	8.16	10.94	5.71	8.17	6.94
155	-	-	-	3.35	4.72	8.02	12.92	13.09	8.57
				Crop season = 2002-03					
35	0.29	0.37	0.48	0.20	0.26	0.33	0.17	0.31	0.39
65	3.29	3.92	3.07	2.89	3.85	4.02	3.20	4.06	5.81
95	7.64	8.66	9.43	8.13	8.10	9.01	6.40	6.64	7.12
125	13.11	9.49	11.12	8.54	8.16	10.94	9.34	10.59	13.83
155	1.68	2.92	1.22	3.35	4.72	8.02	7.96	7.46	4.70

Table 4 Comparison of crop growth rates (g/m²/day) of three *Brassica* species sown during mid November (D_3) under different irrigation regimes and two crop seasons

Days after sowing	*Brassica juncea* cv. RL-1359			*Brassica napus* cv. PGSH-51			*Brassica carinata* cv. PC-5		
	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2
				Crop season = 2001-02					
35	0.13	0.13	0.13	0.22	0.22	0.26	0.19	0.21	0.21
65	4.03	4.04	3.97	2.31	2.42	3.38	1.74	2.10	2.23
95	11.03	12.28	12.26	5.65	5.47	4.87	6.15	6.02	6.08
125	2.99	8.20	8.90	7.08	8.82	12.98	6.99	5.99	7.77
155	-	-	-	0.14	4.97	7.59	-	5.57	9.79
				Crop season = 2002-03					
35	0.20	0.30	0.39	0.35	0.52	1.25	0.26	0.32	0.43
65	4.66	5.19	5.88	3.34	3.92	7.04	3.70	5.76	6.10
95	11.61	9.88	10.09	7.17	6.94	7.55	7.57	6.47	6.41
125	4.98	3.95	7.82	11.79	11.12	8.95	8.67	9.94	11.58
155	-	-	-	-	-	-	4.18	6.30	4.04

Table 5 **Crop yield attributes and yield of three *Brassica* species sown under three dates of sowing and at three irrigation regimes averaged over two crop seasons**

Date of sowing/*Brassica* species/ irrigation treatment	No. of primary branches/m^2	No. of secondary branches/m^2	Pod number/ m^2	1000-seed weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biomass yield (kg/ha)
D_1 : Early October	7	23	189	3.7	1406	5451	9456
D_2 : Late October	7	24	157	3.4	1345	4924	8446
D_3 : Mid November	7	22	123	2.6	1377	4203	7270
CD (Dates) (P=0.05)	0.3	1.3	NS	0.2	NS	545.4	760.6
S_1 : *Brassica juncea*	7	24	153	3.2	1500	5354	9301
S_2 : *Brassica napus*	7	23	173	3.2	1289	4600	7727
S_3 : *Brassica carinata*	7	22	143	3.2	1338	4623	8144
CD (Species) (P=0.05)	NS	1.3	NS	NS	147.3	545.4	760.6
Interaction (Dates x Species) (P=0.05)	NS	2.2	NS	NS	255.2	944.6	1317.4
I_0 : Pre-sowing irrigation alone	7	21	156	3.0	1117	4338	7152
I_1 : Pre-sowing + irrigation at 30 DAS	7	23	150	3.2	1358	4685	8365
I_2 : Pre-sowing + irrigation at 30 DAS + at flowering stage	7	25	164	3.5	1652	5555	9655
CD (Irrigations) (P=0.05)	0.2	0.7	NS	0.1	96.9	470.4	639.5
Interaction (Dates x Irrigations) (P=0.05)	NS	1.3	NS	NS	167.8	NS	NS
Interaction (Species x Irrigations) (P=0.05)	NS	NS	NS	0.19	NS	NS	NS
Interaction (Dates x Species x Irrigations) (P=0.05)	NS	2.2	NS	NS	290.7	NS	NS

Amongst the three species, *B. juncea* cv. RL-1359 produced higher yield attributes followed by *B. carinata* cv. PC-5 and *B. napus* cv. PGSH-51. The total biomass, straw and seed yield revealed a significant interaction for date of sowing and *brassica* species. The yield and yield attributes of three *Brassica* species were significantly influenced by the three irrigation regimes. The seed yield was also significantly affected by interaction of date of sowing, species and irrigation regimes (Table 5).

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Effect of tillage and irrigation regimes on root growth, water removal pattern and water production functions of rice fallow sunflower

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Abstract

Studies on the interaction effects of tillage practices and irrigation regimes on water use, seed yield and water use efficiency of sunflower (*Helianthus annuus* L.) in sandy clay loam Alfisol under rice fallows revealed that significantly higher initial crop stand (81%), root length and root length density and leaf area index was possible when tillage was done with tractor drawn disc plough or MB plough tillage (deep tillage) treatments + rotavator. Sub soil contributed significant proportion for sunflower water requirements in deep tillage practices than shallow and zero tillage practices. The soil moisture removed by sunflower gradually declined with soil depth. Under intense irrigation regimes relatively higher proportion of water removed from surface layers, while under moisture deficit conditions moisture extraction from subsoil layers was in appreciable amounts. Irrigation regime at IW/ CPE = 0.8 recorded higher WUE than IW/ CPE = 0.6, 1.0 and 1.2. Water use (ETa) by sunflower increased with increase in intensity of tillage and irrigation. WUE was higher in deep tillage practices and in irrigation regime of IW/CPE =0.8. Deep tillage, besides saving 18 % irrigation water, resulted in about 17% higher sunflower WUE compared with shallow tillage. The seasonal water production function, as expressed by linear model under various tillage practices and irrigation regimes, performed well for seed yield at more than 94 % variation in the seed yield indicating that seed yield of sunflower is responding to both intensity of tillage and irrigation.

Key words: Tillage, irrigation regime, water use, water use efficiency, sunflower

Introduction

Sunflower (*Helianthus annuus* L.) is fast emerging as a promising succeeding crop in rice fallows in large parts of Southern India. Land preparation for the preceding crop (puddle rice) disturbs the soil structure and soil physical environment due mainly to puddling. This restricts the root growth of subsequent irrigated dry crops thus lowers yield potential of the crop (Reddy and Reddy, 1989). Tillage may help in retention, storage and release of water in soil (Tayler, 1983). The root length density is an important parameter to model water and nutrient movement in root zone and to study soil-root-shoot-atmosphere interaction (Qiang Zuo *et al.*, 1999) Various tillage practices and irrigation levels have been tried for different crops, however information on interaction effects of tillage practices and irrigation regimes for sunflower in rice fallows are not available. The present study aims at examining the suitable land preparatory tillage and their interactions with various irrigation regimes with the key objective of identifying a tillage system and irrigation regime as the most efficient ones for sunflower in rice fallow situations.

Materials and methods

Field experiments were conducted on transplanted low land rice fallow at the University Experimental Farm, Acharya N.G. Ranga Agricultural University, Hyderabad (17° 19' North Latitude and 78° 28' East longitude at an altitude of 535 m above MSL), during *rabi* for two consecutive years (1998 and 1999). The soil (Typic Haplustalf) was medium deep (50 cm deep), sandy clay loam in texture with 66.0, 12.3 and 21.7% sand, silt and clay, respectively with an initial bulk density of 1.5 (0-15 cm), 1.6 (15-30 cm), 1.6 (30-45 cm) Mg/m^3. The moisture % at -0.03 MPa and -1.5 MPa pressure were 16.65 and 5.40 by weight, respectively. The soil was neutral (pH 7.54), non-saline (E.C. 0.174 d Sm-1), medium in organic carbon (0.55%), low in available nitrogen (223 kg/ha) and phosphorus (21.4 kg P_2O_5/ha) and medium in available potassium (287 kg K_2O/ha).

The experiment was laid in Strip Plot (6.6 m x 4.5 m) Design with five tillage treatments *viz.*, T_1 - zero tillage (dibbling of seeds), T_2 - two passages each of bullock drawn desi plough + bollock drawn three tyne cultivator-

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farmers' practice, T_3 - two passages of bullock drawn desi plough + one passage of power tiller drawn rotavator (modified farmers' practice), T_4 - one passage of tractor drawn MB plough + two passages of tractor drawn cultivator and T_5 - one passage each of tractor drawn disc plough + rotavator and four levels of irrigation regimes of 60mm irrigation at IW/CPE ratio of 0.6 (I_1), 0.8 (I_2), 1.0 (I_3) and 1.2 (I_4) superimposed on tillage treatments. The treatments were replicated thrice. Tillage treatments were carried out at around 10% soil moisture content thereby avoiding compaction during tillage operations. The crop (Morden cultivar) with plant to plant and row to row distance of 45 cm and 30 cm received 60 kg N (urea in two equal splits as basal dose and at buttoning stage), 60 kg P_2O_5 (SSP as basal) and 30 kg K_2O (MoP as basal).

Initial plant stand was determined by counting the number of seedlings (hills) each in gross plot twelve days after sowing (DAS). The mean weekly pan evaporation ranged from 4.2 to 8.6 mm/day (average 6.3) and 4.5 to 9.1 mm/day (average 6.7) during crop growth period of 1998 and 1999, respectively. There was no precipitation during the crop growing seasons. The mean weekly maximum and minimum temperatures ranged from 16.9 to 38.1 and 14.6 to 41.3°C during the crop period of the first and second years i.e. 1998 and 1999, respectively. The mean relative humidity ranged from 63 to 89% and 52 to 85% during crop periods of the first and second years, respectively.

After harvest of shoots of sampled plants at 30 and 60 DAS, a spray of a fine jet of water washed the roots and the root soil mixture was suspended in water in the tub of root washing assembly and passed through a 60 mesh sieve sticked over a 100 mesh sieve. The total root length of each sample was determined by Newman's (1966) method as modified by Tennant (1975). Total root length and root length density were calculated as

Total root length (TRL) = 0.786 x number of intersections x grid unit.

Root length density (RLD) = Total root length (cm)/volume of soil sample (cm^3)

An IW/CPE of 0.6, 0.8, 1.0 and 1.2 received 4, 6, 8 and 9 irrigations during 1998 with total amount of irrigation water of 240, 360, 480 and 540 mm respectively, while during 1999 the same treatments were provided 5, 7, 9 and 11 irrigations with total quantity of 300, 420, 540 and 600 mm irrigation water, respectively. To check the entry of water from one treatment to another, a 50 cm wide drain and successive 50 cm levee were constructed between the plots. Irrigation water applied was measured with V- notch weirs. Soil water availability at different soil depths was monitored by determining soil moisture content gravimetrically up to 45 cm soil layer in three depths using core sampler (Michael *et al.*, 1977) just before and 24 h after irrigation for each irrigation cycle. The crop ETa was as computed by the following relation

$$\text{Crop ETa} = \sum_{n=1}^{i=n} \frac{M_1 i - M_2 i}{10} \times \text{pbi} \times \text{Di}$$

In which, ETa = crop evapotranspiration (mm) from the effective root zone depth within an irrigation cycle; n=number of soil layers sampled in the root zone depth; M_{1i} = Mass water percentage 24 hr after n^{th} irrigation in the i^{th} layer, cm; M_{2i} = Mass water percentage just before n^{th} irrigation in the i^{th} layer; pbi = Bulk density of the soil in the i^{th} layer, cm; $\sum$=Summation; I= Integer representing soil layer.

Water use of crop under each irrigation treatment was determined by summing up the ETa values of all the irrigation cycles in a given treatment. Water use efficiency (WUE) is the ratio of economic yield (seed) to the amount of water used by the crop in Eta.

$$\text{WUE (kg/ha/mm)} = \frac{\text{Seed yield (kg/ha)}}{\text{Seasonal ETa (mm)}}$$

Soil moisture extraction pattern (SME) refers to the amount of soil moisture, expressed as percentage, extracted by the plant roots from each layer of the effective root zone depth (45 cm) during crop season. Thus, the seasonal crop ETa values obtained from each layer were expressed as a percentage of seasonal crop ETa from the entire root zone depth in a given treatment and the moisture extraction curves were constructed. The summation of soil moisture extraction in all the soil layers in the effective root zone depth gives the total extraction (100%) as given below:

$$SME_t = SME_1 + SME_2 + SME_3$$

Where, SME_t = Soil moisture extraction from 0-45 cm; SME_1 = Soil moisture extraction from 0-15 cm; SME_2 = Soil moisture extraction from 15-30 cm; SME_3 = Soil moisture extraction from 30-45 cm.

The response of sunflower crop in terms of seed yield to water use (ETa) was ascertained by fitting the following linear function.

$$Y = a + b\ ETa \quad \ldots \quad \text{linear}$$

Where, Y = Seed yield (kg/ha); ETa = Seasonal crop evapotraspiration (mm); a = Y-axis intercept; b = linear regression co-efficient.

Results and discussion

Initial crop stand: High initial crop with rotavator tillage (as secondary tillage) may be attributed to formation of fine tilth resulting in improved seed- soil- water contact and soil physical conditions that are prerequisites for germination and emergence (Table 1). Similar was the case with rotavator used as secondary tillage (81.8% incase of T_5 and 79.7 incase of T_3) compared to cultivator

(67.1% incase of T_4 and 65.86 % in case of T_2) and zero tillage plots (57.5 %). Seedling emergence % was significantly correlated with other soil physical properties *viz*., mean mass diameter of dry clods in the seed bed (-0.961**), soil penetration resistance (-0.411*) and soil moisture content (0.868**) at emergence. The effect of irrigation regimes and their interaction with tillage was not significant on seedling emergence.

Plant height: Plant height increased with increased intensity of tillage and irrigation regimes. Tallest plants were observed under the tillage practice of tractor drawn disc plough or MB plough and in irrigation regime of IW/CPE=1.2, individually and in combination. Favourable soil physical conditions and sufficient water supply in these practices caused sunflower crop to grow taller.

Root growth: Tillage practice in general effected penetration of sunflower tap root (Table 1), longest tap root of 26.5 cm was recorded in tractor drawn primary tillage with Disc plough or MB plough which caused tillage to 26 cm soil depth. Deep tillage reduced penetration resistance of soil as such sunflower roots penetrated to deeper soil depths than shallow tillage practices and zero tillage. Finer soil tilth obtained by rotavator secondary tillage caused better soil-root-water contact and thus encouraged root proliferation. Root length density (RLD) was in general higher in topsoil layer, followed by second layer and least in deeper (3rd) soil layer (Table 1). *Gradual decline in RLD of wheat with soil depth was also* reported earlier by Feng Guang-long and Liu chang-ming (1998). RLD of sub soil layers was found to be significantly more in deep tillage (T_5 and T_4) to that in shallow tillage practices (T_2 and T_3) and zero tillage, however finer tillage in surface layer achieved by rotavator secondary tillage (T_5 and T_3) resulted in good soil-water-root contact, thus caused better rot proliferation recording higher RLD in surface layers.

Water removal pattern from soil: Among tillage treatments deep tillage treatments (T_5 and T_4) registered higher proportions of moisture extraction from lower depths of soil i.e., 15-30 cm and 30-45 cm (Table 2). This might be attributed to creation of favourable soil physical environment (low penetration resistance) up to deeper soil layers, allowing better root penetration and proliferation, which caused higher soil moisture removal by sunflower from deeper depths, compared to shallow tillage (T_3 and T_2) and zero tillage (T_1) treatments. On the other hand the soil in zero tillage (T_1) was hard and compact restricted the root growth and soil moisture extraction. Arora *et al.* (1991), Gill *et al.* (1996) and Meharban Singh and Choudhary (1998) also reported similar observations with deep tillage treatments. As the water application decreased with decrease in IW/CPE, the moisture extraction was relatively more from lower depths indicating that zone of root activity moved to deeper soil layers under these conditions. Daniel Hillel (1999); and Hegde and Havanagi (1989) stated that under field conditions, where soil moisture was uniform and adequate, it is possible to divide the extraction pattern in to two distinct layers, an upper layer in which the root density was greatest and nearly uniform hence water extraction was also more and uniform, and a lower layer in which the roots were relatively sparce and hence the rate of water depletion was low as long as the water content of upper layer was fairly high. These observations corroborate well with the findings in the present study with sunflower.

Water Use (WU): The water use (ETa) of the crop under different tillage practices and irrigations regimes presented (Table 2) indicated that evapotranspiration (ETa) of sunflower under different tillage and irrigation combinations varied from 262 to 495mm. The average ETa of T_1, T_2, T_3, T_4 and T_5 were found to be 354, 374, 391, 403 and 416 mm, respectively. Increased water use with intensity of tillage contributed to favourable soil physical environment for root penetration, air permeability and higher moisture storage in soil. Deep tillage practices (T_4 and T_5) registered 17% increased WUE over shallow tillages (T_3 and T_2). Better root expansion with deep tillage (T_5 and T_4) increased the capability of plants to extract more water from sub soil (Chaudhury *et al.*, 1985; Arora *et al.*, 1991) resulting in greater water use. The mean water use in IW/CPE =1.2 moisture regime was highest (471 mm) compared to IW/ CPE =0.6 (289 mm), 0.8 (356 mm) and 1.0 (433 mm). Increased water availability all along the irrigation cycle throughout crop period under intense irrigation regime enabled the crop to use more water.

Water use efficiency (WUE): Deep -fine tilth obtained in T_5 recorded highest water use efficiency of 3.18 kg/ha/mm which was significantly superior to T_1 (2.07 kg/ha/mm), T_2 (2.51 kg/ha/mm), T_3 (2.72 kg/ha/mm) and T_4 (2.92 kg/ha/mm). The irrigation regimes at IW/CPE of 0.8 (I_2) resulted in highest WUE (2.81 kg/ha/mm). The interaction effect of tillage practices and irrigations was significant. Deep tillage with tractor drawn disc plough+ rotavator (T_5) in combination of IW/CPE= 0.8 was the most efficient with regard to WUE (3.34 kg/ha/mm). Under shallow tillage conditions (T_3 and T_2), the WUE didn't differ significantly for I_2, I_3 and I_4, however, highest WUE with deep tillage (T_4 and T_5) was recorded with irrigation combination of IW/CPE =0.8. The soil in deep tillage practices loosened to deeper depths, improved soil water retention making moisture available to sunflower crop all along irrigation cycles through out crop period. These observations indicate that sunflower responds upto IW/CPE of 1.2 under shallow tillage conditions in rice fallows. Similar observations were also reported by Bhushan *et al.*, (1977) with *Brassica compestris* var toria in silty loam soils and Salih *et al.*(1998) with cotton in clayey soils.

Water production functions of sunflower in rice fallows: The empirical estimates for the relationship between sunflower seed yield and crop water use

(seasonal evapo-transpiration), as expressed by linear water production function, are shown in Table 4. The seasonal water production function, as expressed by linear model under different tillages, performed well for seed yield. The model explained more than 94% variation in the seed yield with the values of coefficient of determination (R^2) being 0.941, 0.951, 0.981, 0.960, 0.975 for T_1, T_2, T_3, T_4 and T_5, respectively, 0.983, 0.966, 0.971, 0.977 for I_1, I_2, I_3 and I_4, respectively. This can be explained that the seed yield of sunflower is responding to both intensity tillage (finer tilth) and irrigation. Total water inputs were linear under the present experimental conditions.

Table 1. Effect of tillage and irrigation regimes on initial plant stand, plant height and LAI and tap root length and density of sunflower

Tillage	Initial plant stand (%)		Plant height (cm) at flowering		Tap root length (cm)		Total root length density (cm/cm^3)		
	1998	1999	1998	1999	19998	1999	0-15 cm	15-30 cm	30-45 cm
T_1	58.64	56.36	73.6	69.6	11.24	10.8	1.52	0.41	-
T_2	66.36	65.36	79.5	77.4	15.17	16.5	2.56	0.74	0.12
T_3	79.10	80.45	82.5	81.9	16.06	15.9	3.50	0.81	0.14
T_4	68.18	66.00	94.4	89.4	27.4	25.9	2.92	1.24	0.32
T_5	80.91	82.72	92.9	88.8	26.7	26.1	3.67	1.60	0.30
I_1	69.42	69.72	79.3	76.3	20.1	20.7	2.21	0.86	0.17
I_2	71.65	72.33	82.9	80.3	19.8	20.6	2.54	0.95	0.19
I_3	71.29	70.29	86.5	83.0	19.5	20.0	2.87	0.92	0.12
I_4	70.23	68.38	88.6	84.3	18.8	19.1	3.08	0.72	0.10
CD (P=0.05)							0.57	NS	NS
Tillage	4.88	4.52	2.63	2.20	1.63	1.37			
Irrigation	NS	NS	1.50	1.15	0.64	NS			

T_1 : Zero tillage; T_2 : Farmers' practice; T_3 : Modified farmers' practice; T_4 : One passage of tractor drawn MB plough + two passages of tractor drawn cultivator; T_5 : One passage each of tractor drawn disc plough + rotavator

Table 2 Effect of tillage and irrigation regimes on moisture removal pattern of sunflower

Tillage	Moisture removal pattern (%)					
	1998			1999		
	0- 15 cm	15- 30 cm	30- 45 cm	0- 15 cm	15- 30 cm	30- 45 cm
T_1	64.7 (211)	29.6 (97)	6.64 (21.5)	66.3 (251)	27.3 (102)	6.84 (25.9)
T_2	62.6 (218)	29.8 (103)	7.92 (26.9)	64.2 (258)	27.9 (110)	7.53 (29.6)
T_3	62.8 (229)	29.5 (107)	7.76 (27.4)	63.8 (268)	28.5 (117)	7.70 (30.9)
T_4	56.9 (215)	31.8 (117)	11.54 (42.1)	60.1 (262)	30.5 (130)	8.75 (36.8)
T_5	57.9 (227)	31.7 (122)	10.55 (39.5)	60.7 (273)	30.7 (136)	8.86 (38.5)
Mean	61.0	30.5	8.88	63.0	29.0	7.93
CD (P=0.05)	3.67	1.33	1.77	2.25	1.37	0.91
I_1	59.0 (151)	31.9 (82)	9.94 (25.6)	59.6 (189)	31.0 (99)	8.84 (28.5)
I_2	59.4 (199)	30.8 (103)	9.80 (33.3)	61.7 (232)	30.0 (113)	8.36 (31.3)
I_3	61.5 (251)	30.0 (123)	8.73 (36.1)	64.2 (292)	28.0 (128)	7.54 (34.5)
I_4	63.9 (280)	29.2 (128)	7.05 (30.9)	66.6 (336)	26.8 (136)	6.99 (35.1)
Mean						
CD (P=0.05)	1.27	NS	1.83	2.55	1.67	NS

Figures in parenthesis are seasonal crop water use in mm.

Table 3 Effect of tillage treatments and irrigation regimes on water use efficiency (kg/ha/mm) of sunflower (pooled data of 1998 and 1999)

Tillage (T)	Irrigation regimes				
	I_1	I_2	I_3	I_4	Mean
T_1	2.1	2.2	2.1	2.0	2.1
T_2	2.5	2.6	2.6	2.5	2.5
T_3	2.6	2.8	2.7	2.7	2.7
T_4	2.9	3.1	2.9	2.8	2.9
T_5	3.1	3.3	3.1	3.1	3.2
Mean	2.6	2.8	2.7	2.6	
CD (P=0.05)					
Tillage (T)	0.18				
Irrigation regime (I)	0.13				
Interaction					
T at I	0.22				
I at T	0.15				

Table 4 Water production functions of sunflower under various tillage and irrigation regimes

Zero tillage	Y= 86.75 + 1.79 X	R^2 = 0.941
Bullock drawn country plough twice + bullock drawn cultivator twice	Y= 4.46 + 2.48 X	R^2 = 0.951
Bullock drawn country plough twice + power tiller drawn rotavator twice	Y = 63.58 + 2.85 X	R^2 = 0.981
Mould board plough once + cultivator twice, both tractor drawn	Y = 58.28 + 2.77 X	R^2 = 0.959
Disc plough once + rotavator twice, both tractor drawn	Y= 58.94 + 3.01 X	R^2 = 0.975
Irrigations at IW/CPE = 0.6	Y= -1665+8.38 X	R^2 = 0.983
Irrigations at IW/CPE = 0.8	Y= -2031+8.47X	R^2 = 0.966
Irrigations at IW/CPE = 1.0	Y= -2498 + 8.46 X	R^2 = 0.971
Irrigations at IW/CPE = 1.2	Y= -2554+8.68 X	R^2 = 0.977

Y = Sunflower seed yield (kg/ha); X = Crop water use (mm)

Conclusion: Significant improvement in water retention in deep tillage practices under rice fallows resulted in better water availability for sunflower. Deep- fine tilth obtained by one passage of tractor drawn disc plough + rotavator resulted in significantly higher initial crop stand, root growth, LAI and crop water use. Root growth and LAI were increased with intensity of irrigation regimes. Deep- fine tillage at irrigation regime of IW/CPE= 1.0 was the best for sunflower production in rice fallows both in terms of yield and WUE. Deep tillage saved irrigation water to the extent of 18%. Secondary tillage operation with one passage of rotavator recorded significantly higher RLD and WUE when compared to that with cultivator. The seasonal water production function, as expressed by linear model under different tillage practices, performed well for seed yield.

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Effect of different nutrient management practices on seed yield and oil output in castor, *Ricinus communis* L. under rainfed situation

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Abstract

Field experiments were conducted during the *kharif*, 2001 and 2002 at 15 farmers' fields located in six villages of Gudlanarva watershed area of Mahaboobnagar district of Andhra Pradesh to find out the best nutrient management practice for getting higher seed and oil yield in castor under rainfed situation on red *chalka* soils. The treatments included were farmers' practice of applying 315 kg DAP/ha (22.5 : 57 : 0 : 0, NPKS kg/ha); 100% recommended dose of fertilizers (60:40:30:20 NPKS kg/ha); 100% RDF + moisture conservation practice (dead furrow for every four lines of crop) and 75% RDF+ cowpea incorporation *in situ* after taking first picking. Moisture content was higher in the treatment where cowpea was incorporated in between castor lines followed by in the treatment where in moisture conservation practice of dead furrow for every four rows of crop was followed. Significantly highest mean yield of 602 kg/ha was recorded in cowpea incorporated plots receiving 75% RDF with the yield response of 33.2% over the farmers' practice (22.5:57:0:0 NPKS kg/ha) followed by with the treatment of 100% RDF + moisture conservation (588 kg/ha) with yield response of 30.1%. Significantly highest mean oil yield of 264 kg/ha and 262 kg/ha were recorded with the treatments of 75% RDF + cowpea incorporation and 100% RDF + moisture conservation, respectively over the farmers' practice. Increase in oil yield with the treatments of 75% RDF + cowpea, 100% RDF + moisture conservation and 100% RDF alone were 34.7, 33.7 and 27.5%, respectively over farmers' practice. Fertilizer application @ 75% RDF + cowpea incorporation *in situ* after taking first picking of crop was found to be best option for increasing the castor seed yield and to economize the recommended N, P and K under rainfed situation.

Key words: Castor, integrated nutrient management, cowpea

Introduction

Castor is one of the important commercial oilseed crops cultivated in the area of 3.92 lakh ha with an average yield of 333 kg/ha in Andhra Pradesh. It is concentrated mainly in three districts *viz.*, Mahaboobnagar, Nalgonda and Ranga Reddy and is cultivated on red sandy soils called as *Chalka* soils which are low in fertility status. The crop is cultivated either as a sole crop on continuous basis or in castor-sorghum rotation in this belt. The continued low stagnation of average yield of castor is mostly due to adoption of traditional agricultural practices being followed over the years without much change except replacement of varieties to some extent.

In this area, uneven distribution and scanty rainfall less than 750 mm is a most limiting factor. Fertilizers usage is severely restricted due to water scarcity, lack of awareness about various integrated nutrient management practices and economic constraints of farmers. Keeping in view the water constraint and lack of nutrient management, the study was initiated to know the effect of nutrient management practices along with moisture conservation on seed yield and oil output of castor grown under rainfed situation.

Materials and methods

Field experiments were conducted for two years (2001 and 2002) in *kharif* season at 15 farmers' fields located in six villages selected in such a way that five each of them located in the ridge, middle and valley areas, respectively in the watershed area of Gudlanarva in Mahaboobnagar district of Andhra Pradesh state. The soils of experimental sites were red *chalka* soils (*Alfisols*) fall under Palem series and moderate to shallow in depth. The soils were slightly acidic to slightly alkaline in reaction (5.9 to 8.0), normal in soluble salt content, low to medium in organic carbon content (0.46% to 0.75%), low in available nitrogen (89-165 kg/ha), medium to high in available phosphorus (38-60 kg/ha) and potassium (180-305 kg/ha). Sulphur in these sites was in a sufficient range (12 ppm). Among the micronutrients, zinc was deficient in some fields. Recommended doses of fertilizer for this region i.e., 60 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha were applied. The fertilizer sources used for N, P and K were area, diammonium phosphate and murate of potash. The treatments consisted of farmers' practice (315 kg DAP/ha -22.5:57:0:0 NPKS kg/ha); 100% recommended dose of fertilizers (RDF: 60:40:30:20 NPKS kg/ha); 100% RDF + moisture conservation practice (dead furrow for every 4 lines of crop) and 75% RDF + cowpea sown in between

lines of crop and incorporated after taking first picking. The rainfall received during the crop period of years 2001 and 2002 were 670 and 696 mm, respectively.

The variety used in this study was kranthi with the spacing of 90 x 90 cm. Fertilizers were applied as per the treatments. One dead furrow was kept for every four rows of castor crop in one treatment (T_3). In another treatment (T_4) cowpea was sown in between the castor crop and was incorporated *in situ* after taking first picking at 35-45 days of crop growth. In this treatment, 75% of recommended dose of fertilizers were also applied.

The treatmentwise seed yields were recorded at the time of harvest. Seed samples were collected from all the treatments and were analysed for oil content by NMR method and oil yield was computed. Moisture content at different depths (0-15 cm, 15-30 cm and 30-45 cm) and at different stages was estimated by gravimetric method.

Results and discussion

Moisture content: The moisture content in surface layer was more at 90 days after sowing (DAS) and then decreased at 120 and 150 DAS in all the four treatments (Table 1). The mean moisture content recorded in the surface layer was more in the treatment where 75% RDF was applied and cowpea was sown in between castor rows, incorporated *in situ* after first picking (T_4) when compared to other treatments. The next highest moisture content was observed in the plots where 100% RDF was applied along with soil moisture conservation practice i.e., one dead furrow for every four castor rows (T_3). The moisture content in 15-30 cm depth was more or less same in both these treatments T_3 and T_4, but whereas, the mean moisture content recorded in lower depth of 30-45 cm was more in the treatment where cowpea was incorporated (T_3) compared to 100% RDF + moisture conservation method (T_4) and other treatments. The organic matter addition to the soil through the incorporation of cowpea might have helped in improving and retaining more moisture content of the soil and to retain more moisture than the other treatments. Uma Devi *et al.* (1991) and Reddy *et al.* (1991) also reported similar results.

Seed yield: Different nutrient management options have significantly affected the yield of castor (Table 2). Significantly highest seed yield of 602 kg/ha (average of 15 farmers' fields) was recorded in the treatment where cowpea was incorporated *in situ* after taking first picking along with 75% of recommended dose of fertilizer (RDF) followed by the treatment of 100% RDF + moisture conservation (588 kg/ha) over farmers' practice (452 kg/ha). Application of 100% RDF itself recorded significantly higher seed yields (569 kg/ha) over farmers' practice. Castor crop grown in shallow red soils might have derived benefit of nitrogen when cowpea is turned into interspaced after sowing and which in turn increased the seed yield. The yield responses with 75% RDF + cowpea incorporation, 100% RDF + moisture conservation and 100% RDF alone were 33.2, 30.1 and 25.9%, respectively over the farmers' practice. In this rainfed region, the moisture conservation practices and integrated nutrient approach might have helped to in supplying nutrient to the crop and in turn increasing the crop yields. Bheemaiah *et al.* (1998) made similar findings in castor crop where the yields were high with green leaf manuring and nitrogen applications. Similar results were also reported in *rabi* sunflower by Reddy *et al.* (2003). The lower yield recorded in treatment where farmers' practice was due to application of lower doses of fertilizers (22.5:57:0:0 NPKS kg/ha).

Table 1 Moisture content (%) of soil samples in farmers' fields at different periods of crop growth during crop season at 0-15 cm depth (2001 and 2002)

Year	Depth	T_1			T_2			T_3			T_4		
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
2001	Range 0-15 cm	6.2-9.0	5.8-8.6	3.1-4.3	6.8-9.5	6.7-9.0	3.0-4.2	7.4-9.9	7.9-9.2	3.7-4.6	7.6-10.3	7.2-9.8	3.4-4.2
	15-30 cm	7.8-10.5	7.0-9.7	4.7-5.8	7.9-10.7	7.7-10.1	4.6-5.6	8.3-11.0	9.1-10.2	5.2-5.9	8.2-11.0	8.7-10.8	5.0-5.7
	30-45 cm	9.4-11.5	8.7-11.2	5.9-7.3	10.5-11.8	9.1-11.4	6.3-7.2	11.0-12.1	10.3-11.1	6.0-7.5	10.9-12.1	10.0-11.6	6.3-7.3
	Mean 0-15 cm	7.5	7.0	3.8	7.9	7.5	3.6	8.7	8.4	4.2	9.0	8.4	3.8
	15-30 cm	9.0	8.3	5.2	9.3	8.9	5.1	9.7	9.6	5.6	9.5	9.8	5.3
	30-45 cm	10.5	10.6	6.6	11.2	10.4	6.7	11.4	10.8	6.6	11.7	11.0	6.7
2002	Range 0-15 cm	6.4-9.2	5.1-7.8	2.0-3.9	7.4-9.4	5.0-8.14	2.8-4.3	7.8-9.5	5.6-8.6	3.1-4.4	8.1-10.1	6.2-9.0	3.2-4.5
	15-30 cm	7.8-11.2	7.1-9.1	4.4-6.6	8.7-10.9	6.4-9.4	3.9-5.6	9.0-10.6	6.8-9.5	4.3-5.7	9.7-11.5	7.6-10.2	4.6-5.8
	30-45 cm	9.3-12.5	7.8-10.4	5.1-7.2	10.6-12.0	7.8-10.6	5.3-6.6	12.2-10.4	8.2-10.7	5.6-6.9	11.0-12.9	9.1-11.4	5.8-7.0
	Mean 0-15 cm	7.8	6.5	4.0	8.3	6.6	3.6	8.5	6.9	3.7	8.9	7.3	3.9
	15-30 cm	9.6	7.8	5.5	9.7	8.0	4.8	9.8	7.5	5.1	10.5	8.7	5.2
	30-45 cm	11.0	9.2	6.2	11.2	9.3	5.9	11.2	9.6	6.2	12.0	10.4	6.3

S_1 : 90 DAS; S_2 : 120 DAS; S_3 : 150 DAS; T_1 : Farmers practice; T_2 : 100% RDF; T_3 : T_2 + moisture conservation; T_4 : 75% RDF + cowpea

Table 2 Effect of different nutrient management options on castor seed and oil yield in farmers' fields during the seasons 2001 and 2002 (Pooled data)

Treatment	Mean seed yield (kg/ha)			Mean oil yield (kg/ha)			Mean seed oil content (%)	Cost benefit ratio over farmers' practice
	2001	2002	Mean	2001	2002	Mean		
T_1 : Farmers' practice	456	448	452	198	194	196	43.5	-
T_2 : 100% RDF	576	562	569 (25.9)	253	247	250 (27.5)	44.1	1:2.1
T_3 : 100% RDF + moisture conservation	600	577	588 (30.1)	267	257	262 (37.7)	44.4	1:2.6
T_4 : 75% RDF + cowpea incorporation	607	597	602 (33.2)	267	261	264 (34.7)	43.9	1:4.1
Mean	560	546	-	246	240	-		
CD (P=0.05)	14.9	13.6	13.0	6.4	6.8	4.5		

Figures in parenthesis are per cent response over farmers practice.

Oil content: The oil content in castor seed was significantly higher (44.4%) in the treatment 100% RDF + moisture conservation followed by the treatment 75% RDF + cowpea incorporation (43.9%) and 100% RDF alone (44.1%). The oil content was less i.e., 43.5% in seed obtained from the farmers' practice plots. The application of sulphur which is included in recommended dose of fertilizer schedule may be the probable reason for increasing the oil content in seed in the treatment where RDF was applied in full or in partial over the farmers' practice. Bhagat and Soni (2000) reported the same trend in mustard crop.

Oil yield: Significantly higher mean oil yield was recorded in the treatments 75% RDF + cowpea incorporation (264 kg/ha) and 100% RDF + moisture conservation (262 kg/ha) over 100% RDF alone and farmers' practice. Application of recommended dose of fertilizer alone has resulted significantly higher oil yield than farmers' practice. The increase in oil yield over the farmers practice with respect to treatments 75% RDF + cowpea incorporation, 100% RDF + moisture conservation and 100% RDF alone were 34.7, 33.7 and 27.5%, respectively. The lowest oil yield of 196 kg/ha was recorded with farmers' practice. The increased seed yield and oil content due to various moisture conservation practices lead to increase the castor oil yield. Reddy *et al.* (2003) reported similar results in *rabi* sunflower crop.

Benefit cost ratio: Cost benefit ratio for all the treatments was derived after taking into consideration the cost of all the inputs and cultivation practices and it was found that 75% RDF along with cowpea incorporation *in situ* (T_4) has given the highest cost benefit ratio of 1:4.1 than all other treatments. Reddy *et al.* (2003) also reported similar results.

From the above study, it could be concluded that the fertilizer application @ 75% RDF with cowpea incorporation *in situ* after first picking of crop was found to be the best option among the treatments tested in the scanty rainfall zone of Mahaboobnagar district in Andhra Pradesh for better moisture conservation and to get the increased seed and oil yields besides economizing the recommended NPK and S.

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Intercropping in castor, *Ricinus communis* L. under irrigated condition

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Abstract

A field experiment was conducted on the loamy soils during *kharif* seasons of 2002-03 to 2004-05 to study the effect of intercropping under irrigated castor. Intercropping of either 1 or 2 lines of greengram or one line of sesame produced significantly higher castor equivalent yield over sole castor system. Castor + greengram (1:1) produced the highest equivalent yield (3895 kg/ha) with more net realisation and B:C ratio (3.41).

Key words: Castor, intercropping, row ratio and castor equivalent yield

Introduction

Castor is an important non-edible industrial oilseed crop of North Gujarat. The state occupies the top position in area (3.04 lakh ha) and production (4.65 lakh tonnes) and productivity (Damodaram and Hegde, 2002). In Gujarat its cultivation is mainly confined to North Gujarat, Saurashtra, Kutchh and Middle Gujarat both as a sole crop and as an intercrop/mixed crop. However, it is ideally suited for intercropping system by virtue of its drought tolerance, perenniating nature, branching habit and indeterminate penology (Hegde and Sudhakara Babu, 2002; Anjani *et al.*, 2002). Also its long duration, slow growth during initial stage, hardy growth with deep tap-root system and wide spacing offer a scope to introduce short duration intercrops. With a view to generate the information on suitability of intercropping in castor, the present study was undertaken with different intercrops and row ratio.

Materials and methods

Field experiment was conducted at the Main Castor-Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar, Gujarat during *kharif* seasons of 2002-03 to 2004-05. The soil of the experimental plot was loamy sand in texture with pH 7.8. It was low in organic carbon (0.15%) and available nitrogen (168 kg/ha), medium in available phosphorus (43 kg/ha) and high in available potash (338 kg/ha). The amount of rainfall and its distribution is furnished in Table 1. Seeds of castor hybrid GCH-5 were dibbled adopting a spacing of 120 cm x 60 cm and intercrops as per the treatments (Table 2) were sown on 15th, 9th and 6th July in the year 2002, 2003 and 2004, respectively. The experiment comprising of seven treatments was conducted in Randomized Block Design with three replications. Three intercrops *viz.*, greengram (GM-4), sesame (GT-1) and mothbean (GMO-1) were used as test crops with different row ratio. A recommended dose of fertilizers to all the crops was applied based on the proportion of planting density of the intercrops. The crops were sown under rainfed condition, but after cessation of monsoon eight irrigations, each of 50 mm depth were given to castor crop at an interval of 15-20 days. Pest and disease control measures were taken as and when required. Greengram matured in 65 days, sesame in 95 days and moth bean 120 days. The castor beans were picked at 120, 150, 180 and 210 days after sowing. The quantum and distribution of rainfall during cropping season as given in Table 1.

Results and discussion

The data on seed yield of different crops revealed that the amount and distribution of rainfall had considerable influence on seed yield of the crop under study (Table 3). During 2003, medium rainfall with good distribution in favoured good crop growth and yield of main as well as intercrops. During 2002 and 2004, low and well distributed rainfall favoured crop growth of intercrop which resulted in optimum seed yield. During February, 2002, rain did not influence castor seed yield.

The length of primary spike was significantly reduced in all the intercropping treatments during 2002 and 2003. The number of capsules/primary spike was significantly lower in all the intercropping treatments compared to the sole crop in the year, 2002. During 2003 and 2004, number of capsules/primary spike in castor + greengram (1 or 2 rows) was significantly at par with sole castor. Test weight and oil content were not influenced by different treatments. Castor intercropped with 1 or 2 rows of greengram produced higher seed yield of castor, but was on par with sole castor in all the years. The pooled data also showed that intercropping of greengram (1 or 2 rows) or sesame (1 or 2 rows) recorded castor seed yield on par with castor sole treatment indicating that intercropping of these crops in castor had a complementary effect on castor seed yield. Intercropping of mothbean reduced castor yield as compared to sole castor in all the years. This may be attributed to longer period of competition exerted by mothbean. This suggests the compatibility of these crops for intercropping. The present results are in conformity with the findings of Gupta and Rathore (1993). The data on castor equivalent yield indicated that intercropping of

greengram (1 or 2 rows) and sesame (1 or 2 rows) produced higher equivalent yield over sole castor during all the years. The pooled castor equivalent yield data showed that intercropping of greengram (1 or 2 rows) and sesame (1 row) produced significantly higher castor equivalent yield than sole castor. This study suggests the stability and compatibility of greengram or sesame as intercrop in castor. Among the different treatments, intercropping of one row of greengram or one row of sesame realised maximum net return/ha with benefit : cost ratio.

Thus, from the foregoing discussion it can be concluded that one row of greengram or sesame can be profitably intercropped in castor spaced at 120 cm x 60 cm for obtaining higher net return.

Table 1 Quantity and distribution of rainfall during cropping season in different years at SDAU, Sardarkrushinagar

Month	2002		2003		2004	
	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days
July	18.5	2	239.3	14	14.2	1
August	38.4	7	114.9	9	198.8	15
September	58.0	2	142.7	4	9.0	1
October	-	-	-	-	32.6	3
November	-	-	-	-	-	-
December	3.6	1	-	-	-	-
January	2.0	2	-	-	-	-
February	50.4	2	-	-	-	-
Total	170.9	16	496.9	27	254.6	20

Table 2 Yield attributes, test weight and oil content (%) influenced by different intercropping patterns in castor under irrigated conditions

Treatment	Primary spike length (cm)			No. of capsules/ primary spike			Effective branches/ plant			100-seed weight (g)			Oil content (%)		
	2002	2003	2004	2002	2003	2004	2002	2003	2004	2002	2003	2004	2002	2003	2004
Sole castor (120 x 60 cm)	75	57	55	100	70	81	5	4	4	29.3	30.3	31.4	49.8	49.8	50.5
Castor + Moong 1:1	60	43	54	78	67	81	3	4	3	28.1	29.9	30.9	49.7	50.2	49.9
Castor + Moong 1:2	62	42	52	45	69	77	3	4	3	27.1	30.7	31.7	49.1	49.9	49.4
Castor + Sesame 1:1	55	41	52	73	65	78	3	3	3	28.9	30.3	31.6	48.9	48.7	49.8
Castor + Sesame 1:2	53	36	52	72	52	72	4	3	3	29.1	32.5	32.0	48.3	49.6	49.5
Castor + Mothbean 1:1	49	35	52	61	41	77	3	2	3	30.9	30.0	29.5	50.0	50.3	50.0
Castor + Mothbean 1:2	46	33	50	60	31	72	3	2	3	29.8	29.9	29.9	49.9	48.7	49.9
SEm±	2	3	2	3	2	2	0.2	0.2	0.3	0.8	0.7	0.7	0.3	0.5	0.4
CD (P=0.05)	6	8	NS	8	5	4	0.6	0.9	NS	NS	NS	NS	1.0	NS	NS

Table 3 Seed yield of castor, intercrops and castor equivalent yield influenced by different intercropping systems

Treatment	Castor and intercrop yield (kg/ha)				Castor equivalent yield (kg/ha)			
	2002-03	2003-04	2004-05	Pooled	2002-03	2003-04	2004-05	Pooled
Sole castor (120 x 60 cm)	2604	3797	2541	2980	2604	3797	2541	2980
Castor + Moong 1:1	2730 (693)	4127 (696)	2906 (556)	3310 (648)	3358	4659	3488	3895
Castor + Moong 1:2	2414 (848)	3897 (974)	2634 (665)	2982 (829)	3386	4642	3279	3769
Castor + Sesame 1:1	2275 (690)	4036 (425)	2635 (225)	2982 (446)	3129	4869	3111	3703
Castor + Sesame 1:2	1989 (874)	3584 (447)	2108 (352)	2560 (557)	3057	4428	2853	3446
Castor + Mothbean 1:1	1459 (498)	2883 (323)	2213 (264)	2185 (361)	2095	3144	2578	2606
Castor + Mothbean 1:2	1416 (448)	2818 (374)	2289 (405)	1941 (459)	2021	2465	2436	2307
SEm±	82	278	130	173	142	281	148	181
CD (P=0.05)	254	857	399	534	347	868	458	558

Data in parenthesis are intercrop yield (kg/ha).

Table 4. Economics influenced by different intercropping systems

Treatment	Castor of cultivation (Rs/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Sole castor (120 x 60 cm)	12500	50660	12500	38160	3.05
Castor Moong 1:1	15000	66215	15000	51215	3.41
Castor + Moong 1:2	16250	64073	16250	47823	2.94
Castor + Sesame 1:1	14500	62951	14500	48451	3.34
Castor + Sesame 1:2	15500	58582	15500	43082	2.77
Castor + Mothbean 1:1	15000	44302	15000	29302	1.95
Castor + Mothbean 1:2	16250	39219	16250	22969	1.41

Selling prices: Rs/kg Castor: 17.00; Mungbean : 18.00; Sesame : 36.00 and Mothbean : 12.00

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Integrated nutrient management for castor-sorghum (fodder) cropping system

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Abstract

A field experiment was conducted on deep sandy loam soils of North Gujarat region during *kharif*, 1999-00 to 2001-02 to study the effect of integrated nutrient management on growth, yield attributes, seed yield, castor equivalent yield and economics in castor-fodder sorghum cropping system under irrigated conditions in North agro-climatic zone of Gujarat. Application of recommended dose of N through inorganic fertilizer in combination with castor cake substituting 25 or 50% N significantly increased plant height, effective branches/plant, length of main spike and number of capsules/main spike over 100% inorganic fertilizer as well as its combination with FYM to substitute 25 or 50% N. The significantly highest seed yield was recorded when 50% N was substituted with FYM which was on par with 25% substituted with FYM and 50% through castor cake. Direct effect of 100% RDF to sorghum gave significantly higher sorghum fodder yield than 75% RDF. The residual effect of INM given to previous castor crop was evident. The significantly highest fodder yield was recorded with substitution of 25% N through castor cake which was on par with 50% N through FYM but superior over 100, 75 and 50% RDN through inorganic fertilizers.

Key words: Castor, fodder sorghum, organic and inorganic

Introduction

Gujarat is a leading state in castor production, which contributes 80.8% of total production in India. North Gujarat agro-climatic zone grows 63.6% of castor of Gujarat. In this region, dairy industry is well established so, farmers required dry fodder in livestock farming systems, which is predominant in these areas. Generally, the farmers follow castor-summer bajra/fodder sorghum cropping sequence. The soils of North Gujarat are mostly sandy loam to loamy sand in texture and low in organic carbon (0.21%), available nitrogen (169 kg/ha) and phosphorus (19.2 kg/ha) and high in available potassium (332 kg/ha). Integration of organic and inorganic has been found to be quite promising not only in maintaining higher productivity but also in providing greater stability in crop production. Popularising the use of organics to reduce the dependence on chemical fertilizers and to contribute to pollution free environment is the greatest need of the hour. Farm yard manure and castor cake have been advocated as a good organic manure and easily available source for use in integrated nutrient management programme in field crops. Therefore, there is an urgent need to develop a system using organics and inorganics on the complementary basis, which may enhance the efficiency and simultaneously reduce the requirements of inorganic. Presently fertilizer application is based on the nutrient requirement of individual crop and the carryover effect of the manures or fertilizers applied to preceding crop are generally ignored. Further, application of inorganic fertilizers even in balanced amount does not sustain the soil fertility and productivity under continuous cropping. Integration of organic, inorganic, crop residue and bio-fertilizers may improve the soil productivity (Patra *et al.*, 2000; Kumar *et al.*, 2001) and system productivity becomes sustainable (Nambiar and Abrol. 1992). Hence, a study was initiated to identify the suitable integrated nutrient supply system to get the maximum sustainable production for castor-fodder sorghum cropping system for the North Gujarat region.

Materials and methods

A fixed plot experiment was conducted on deep sandy loam soils of North Gujarat during *kharif*, 1999-00, 2000-01 and 2001-02 at Main Castor-Mustard Research Station, Sardarkrushinagar-Dantiwada Agricultural University, Sardarkrushinagar (Gujarat). The soil of the experimental site was sandy loam with pH 7.9, low in available organic carbon (0.21%), available nitrogen (169 kg/ha) and available P_2O_5 (19.1 kg/ha) and high in K_2O (332 kg/ha) with soil pH 7.9, B.D. 1.56 g/cubic cm, F.C. 7.84%, PWP 2.41% and WHC 20%. The total rainfall during crop period from July to March was 149.6, 400 and 484.8 mm during 1999-00, 2000-01 and 2001-02, respectively. The treatment details are given in Table 1. The organics were FYM (0.45% nitrogen) and castor cake (4.5% nitrogen). The recommended level of fertilizer for castor is 200 kg N and 50 kg P_2O_5/ha and for fodder sorghum is 80-40 NP

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kg/ha. The inorganics were supplied through urea and DAP. The experiment was laid out in Split Plot Design with three replications. The GCH-4 castor hybrid was sown at a spacing of 90 x 60 cm on 23rd July, 1999, 8th August, 2000 and 18th July, 2001 and was harvested upto 15th March in all the three years. The GFS-4 fodder sorghum variety was sown with 30 cm row to row spacing on April 8th, 5th and 7th and was harvested on June 7th, 5th and 7th during 1999-00, 2000-01 and 2001-02, respectively. The organics were applied as band placement in furrow 7 days before sowing as per treatment. Entire dose phosphorus and 40 kg N/ha (as per treatment) was applied to castor as basal, and the remaining N was topdressed at 40, 70, 100 and 130 DAS and full dose phosphorus and half dose of nitrogen were applied as basal and remaining half of nitrogen was applied at 25 DAS to sorghum crop. Eight irrigations were given to castor after cessations of monsoon among them first 4 irrigations at 15 days interval and remaining 4 irrigations at 20 days interval whereas sorghum received 6 irrigations i.e., first irrigation after sowing, second 3rd DAS for uniform germination and establishment other irrigations were given at 25, 32, 40, 50 and 55 DAS, respectively. The remaining package of practices of castor and sorghum crop were followed as recommended.

Results and discussion

The application of recommended dose of N in form of inorganic fertilizer combination with substituting 25 or 50% N through FYM or castor cake increased plant height, number of effective branches/plant, length of main spike and number of capsules/main spike over 100% inorganic fertilizer. Residual effect of fertilizer applied to previous crop of sorghum was also found significant in most of the years for plant height, length of main spike and number of effective branches/plant (Table 1). Similar findings were also made from Andhra Pradesh (Baby Akula and Bapi Reddy, 1998). This increase in yield attributes was owing to improvement in physico-chemical properties of the soil and more availability of nutrients and moisture to plants (Nambiar and Abrol, 1992; Patra *et al.*, 2000 and Kumar *et al.*, 2001), which supported our findings. The interaction was found significant for plant height during 2000 and 2001, capsules/main spike in the year 1999 and 2001, effective branches/plant in year 2000 and length of primary spike in 2001 (Table 2). The treatment combination of 25% or 50% N through castor cake or FYM to castor with 100% FRD to sorghum recorded significantly higher values of plant height, length of primary spike, capsules/primary spike and effective branches/plant.

Effect on castor seed yield: The pooled data showed that the application of recommended dose of N through inorganic fertilizer in combination with castor cake substituting 50% N and with FYM substituting 25 or 50% N, significantly increased castor seed over 100% inorganic fertilizer as well as its combination with castor cake to substitute 25% N (Table 1). The significantly highest seed yield was recorded when 50% N was substituted with FYM (C_5) which was on par with 25% substituted with FYM (C_4) and 50% through castor cake (C_7). The beneficial effect of substituting recommended N by 25 or 50% through FYM or 50% N through castor cake was evident. The residual effect of 100% and 75% FRD treatments had non-significant effect on castor seed yield. The interaction was found significant for seed yield of castor in the year 2000-2001. The treatment combination of substitution of 25% N through FYM to castor crop with 100% FRD to sorghum recorded significantly higher seed yield of castor (Table 3). Organic source played a key role in enhancing efficient utilization of the native as well as applied nutrients through matching nutrient availability with crop requirement to exhibit crop's productive capacity. These organic sources also supply some micro nutrients and growth promoting substances, which might have helped in higher capsules/primary spike, higher branches/plant and length of primary spike.

The interaction effect of C x Y was significant (Table 1). Effect of the treatments given to castor varied on castor yield in different years. In the first year C_6 and C_7 were significantly superior to C_1 whereas C_4 and C_5 were on par with C_1. Whereas in the second and third year C_4, C_5 and C_7 were better than C_1 but C_6 was on par with C_1 in their effects. The mean values showed the superiority of C_4, C_5 and C_7 over C_1, which was consistent in the second and third years. These results are corroborating with the findings of Anonymous (1992); Baby Akula and Bapi Reddy (1998) and Patel and Pathak (2002).

Effect on dry fodder yield: Direct effect of 100% FRD to sorghum gave significantly higher sorghum fodder yield than 75% FRD (Table 2). The residual effect of INM given to previous castor is evident. The significantly highest fodder yield was recorded with substitution of 25% N through castor cake which was on par with 50% N through FYM but superior over 100, 75 and 50% RDN through inorganic fertilizers.

The interactive effect of CxY on fodder sorghum yield was significant (Table 3). Effect of the treatments was non-significant in the first and third year but during the second year the INM treatments increased the yields so high over the control, its impact remained on the pooled values also. The interactive effect of SxY on sorghum fodder yield was significant. During the third year, the treatment differences were non-significant whereas in the first and second years 100% FRD gave higher yield than 75% FRD and the pooled values also provided similar significant result.

To workout the combined effect of direct and residual effect of fertilizers, equivalent castor yield was worked out. The direct application of inorganic fertilizers in combination with organics 25 or 50% N through FYM or castor cake was found significant, whereas, 100% and 75% FRD to

sorghum crop was non-significant (Table 4). The significantly highest castor equivalent yield (3382 kg/ha) was observed in substitution of 50% N through FYM which was on par with 50% N through castor cake as well as 25% N through FYM and castor cake but significantly superior over inorganic fertilizers over 100, 75 and 50% treatment. The higher castor equivalent yield was recorded with 100% FRD to sorghum crop as compared to 75% FRD to sorghum crop. The interactive effect of C x Y on castor equivalent yield (pooled) was significant. The results were similar to C x Y on castor yield indicating the dominance of castor yield over that of fodder sorghum yield in the equivalent castor yield.

The castor yield as well as the castor equivalent yield values showed that, among the four INM treatments, C_4, C_5 and C_7 were superior to C_1, whereas C_6 was on par with C_1 in their effects. Between C_4, C_5 and C_7, the cost of input cultivation was high for C_7 and therefore the CBR values of C_4 and C_5, which were superior to the rest, were considered for recommending these two treatments (Table 3).

Thus, it can be concluded that farmers of North Gujarat (AES) growing castor (GCH-4) in *kharif* with recommended dose of N (200 kg/ha) are advised to substitute 25 or 50% N by FYM to get the higher yield and an additional income over 100% recommended fertilizer. For the subsequent sorghum fodder crop in summer 75% of recommended N is sufficient.

Table 1 Growth and yield attributes of castor as influenced by integrated nutrient management in castor-fodder sorghum cropping system

Treatment	Plant height (cm)			Length of main spike (cm)			No. of effective branches/plant			No. of capsules/main spike		
	1999-00	2000-01	2001-02	1999-00	2000-01	2001-02	1999-00	2000-01	2001-02	1999-00	2000-01	2001-02
Direct effect (D)												
C_1 : 100% RDF	47	37	44	40	44	36	3	4	3	56	41	48
C_2 : 75% RDF	42	36	45	38	41	36	3	4	3	52	39	51
C_3 : 50% RDF	41	34	42	36	40	32	3	4	3	56	37	33
C_4 : 75% RDF + 25% N(FYM)	46	41	55	44	42	33	3	4	4	52	38	50
C_5 : 50% RDF + 50% N (FYM)	49	46	61	43	45	36	4	4	4	53	37	57
C_6 : 75% RDF + 25% N (castor cake)	54	47	48	45	46	36	4	5	3	56	43	47
C_7 : 50% RDF +50% N (castor cake)	52	50	49	46	46	42	4	4	4	57	44	46
SEm±	1.1	2.3	1.6	1.2	2.6	1.0	0.1	0.3	0.2	1.6	27	1.5
CD (P=0.05)	3.5	7.1	5.0	3.6	NS	3.2	0.4	NS	0.5	NS	NS	4.6
CV (%)	5.8	13.6	8.1	7.0	14.4	7.0	9.4	16.5	11.0	7.2	16.4	7.7
Residual effect ®												
S_1 : 100% FRD	49	43	49	43	42	37	4	4	4	56	41	47
S_2 : 75% FRD	46	40	49	39	45	35	3	4	3	53	39	47
SEm±	0.5	0.7	0.4	0.6	0.6	0.3	0.1	0.1	0.1	0.7	1.9	0.5
CD (P=0.05)	1.5	2.1	NS	1.8	2.0	1.0	0.2	NS	0.3	2.1	NS	NS
CV (%)	4.8	7.8	3.3	6.5	6.8	4.2	7.3	9.9	13.3	5.9	14.5	5.0
Interaction	NS	Sig.	Sig.	NS	NS	Sig.	NS	Sig.	NS	Sig.	NS	Sig.

Table 2 Interactive effect between DxR on growth and yield attributing characters of castor

Fertilizer applied to castor	Fertilizer applied to castor											
	Plant height (cm)				No. of capsules/main spike				No. of effective branches/plant		Length of main spike (cm)	
	2000-01		2001-02		1999-2000		2000-01		2000-01		2001-02	
	100% FRD	75% FRD	100% FRD	75% FRD	100% FRD	75% FRD	100% FRD	75% FRD	100% FRD	75% FRD	100% FRD	75% FRD
C_1 : 100% RDF	38	35	44	44	58	54	45	45	4	4	37	36
C_2 : 75% RDF	39	32	44	46	49	56	54	48	4	4	38	34
C_3 : 50% RDF	37	32	42	42	59	54	35	31	3	4	30	33
C_4 : 75% RDF + 25% N(FYM)	44	38	55	55	55	49	48	52	5	4	34	33
C_5 : 50% RDF + 50% N (FYM)	44	48	61	61	56	51	55	58	4	5	37	36
C_6 : 75% RDF + 25% N (castor cake)	50	43	51	44	59	53	48	46	5	4	36	35
C_7 : 50% RDF +50% N (castor cake)	47	51	49	50	60	55	47	44	4	5	44	43
SEm±	1.9		0.1		1.87		1.4		0.24		0.9	
CD (P=0.05)	5.6		2.9		5.59		4.2		0.74		2.7	

Table 3 Seed yield of castor, castor equivalent yield and economics influenced by integrated nutrient supply in castor-sorghum cropping system

Treatment	Castor seed yield (kg/ha)				Castor equivalent yield (kg/ha) of the castor-fodder sorghum cropping system				Gross return (Rs/ha)	Total cost (Rs/ha)	Net return (Rs/ha)	CBR
	1999-00	2000-01	2001-02	Pooled	1999-00	2000-01	2001-02	Pooled				
Direct effect (D)												
C_1 : 100% RDF	1565	1727	1987	1759	2393	2095	2730	2406	30075	16445	13630	1.83
C_2 : 75% RDF	1299	1995	2029	1774	2107	2884	3252	2747	34338	15914	18424	2.16
C_3 : 50% RDF	959	1703	1878	1513	1742	2668	2626	2345	29313	15382	13931	1.90
C_4 : 75% RDF + 25% N(FYM)	1709	2932	2655	2432	2535	3759	3357	3217	40213	17303	22910	2.32
C_5 : 50% RDF + 50% N (FYM)	1737	2723	3018	2493	2583	3756	3809	3382	42275	18160	24115	2.33
C_6 : 75% RDF + 25% N (castor cake)	1942	2012	1913	1955	2786	3277	2829	2964	37050	17968	19082	2.06
C_7 : 50% RDF +50% N (castor cake)	1874	2513	2728	2372	2733	3543	3407	3227	40338	19489	20849	2.07
SEm±	123	122	121	86	114	272	144	183	-	-	-	-
CD (P=0.05)	380	376	374	266	351	837	442	563	-	-	-	-
CV (%)	19.0	13.3	12.8	17.9	11.5	21.2	11.1	15.9	-	-	-	-
Residual effect ®												
S_1 : 100% FRD	1624	2315	2268	2069	2474	3160	3174	2936	36700	16445	20255	-
S_2 : 75% FRD	1543	2143	2363	2016	2346	3120	3114	2861	35763	16034	19729	-
SEm±	33	61	58	25	34	144	70	55	-	-	-	-
CD (P=0.05)	NS	NS	NS	NS	104	NS	NS	NS	-	-	-	-
CV (%)	9.5	12.5	11.4	9.6	6.5	21.0	10.2	14.9	-	-	-	-

Table 4 Interaction effect between DxR on seed yield (kg/ha) of castor (2000-2001

Fertilizer applied to castor	Fertilizer applied to sorghum	
	100% FRD	75% FRD
C_1	1565	1885
C_2	1973	2017
C_3	1775	1631
C_4	3329	2535
C_5	2634	2811
C_6	2237	1783
C_7	2690	2337
SEm±	161	
CD (P=0.05)	489	

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Performance of castor, *Ricinus communis* grown in different planting geometries and intercropped with different row proportions of groundnut or pearl millet

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Abstract

A field experiment was conducted to study the performance of castor grown in different planting geometries and intercropped with different row proportions of groundnut/pearl millet during *kharif* season on sandy loam soils under rainfed conditions. There were 14 intercropping treatments with different planting geometries of castor intercropped with 1 to 7 rows of groundnut or pearl millet and sole crop treatments. The results showed that the planting geometry of castor at 180 x 13 cm spacing with 5 rows of intercropped groundnut or the spacing of castor at 120 x 20 cm with 3 rows of pearl millet did not influence the plant height, number of leaves, leaf area/plant, phytomass/plant, length of spike, number of capsules/spike and seed yield/plant. Castor yielded on par with the sole crop by these intercropping treatments during both the years.

Key words: *Intercropping, planting geometry,* growth, yield components and yield

Introduction

Castor thrives well on poor textured soils and low rainfall ecosystems, which usually do not support other commercial crops (Singh and Singh, 1988; Jadhav *et al.*, 1992). Andhra Pradesh ranks next only to Gujarat both in area and production. It is predominantly cultivated in the drought prone economically backward districts of Nalgonda, Mahboobnagar and Ranga Reddy. Its cultivation is expanding in the hitherto non-conventional areas. The soils of these districts are sandy and shallow in depth coupled with erratic rainfall. The crop is usually sown with seed drills at a spacing of 90-150 cm between the rows with no definite intra row spacing. Research reports unveil the fact that these wide row spaces can be efficiently utilized to grow compatible intercrops to minimize the risk of crop failures under aberrant weather and increase the productivity per unit area in events of good rainfall (Yadava, 1992; Kumar *et al.*, 1995). Pearl millet is also the handy crop to the farmers owing to its drought endurance capacity and early maturity. Groundnut is also an admired crop of the dryland areas. Hence, an experiment was conducted to explore the possibilities of intercropping groundnut or pearl millet in castor grown with varying planting geometry.

Material and methods

A field experiment was carried out in *kharif* 2001 and 2002 at the Agricultural College Farm, Rajendranagar, Hyderabad. The soil was sandy loam in texture slightly alkaline in reaction with 7.8 pH, low in available nitrogen (190.4 kg N/ha), medium in phosphorus (26.5 kg P_2O_5/ha) and rich in potassium (495.0 kg K_2O/ha). There was a rainfall of 566 mm in 33 rainy days during the first year and 449.1 mm in 30 rainy days during the second year during crop duration.

The experiment was laid out in Randomized Complete Block Design (RCBD) with 15 treatments replicated thrice. The plant density of castor cv. Kranti was maintained at 41,000 plants/ha by increasing the spacing between the rows to accommodate more number of rows of intercrops while appropriately reducing the intra row spacing. The groundnut variety Vemana and pearl millet variety Mallikarjuna were used in the experiment.

Results and discussion

Growth parameters: The performance of castor was modified by the planting geometry and number of rows of intercropped groundnut or pearl millet. The competitive effects were more in the first year due to the erratic distribution of rainfall pattern. The plant height of castor intercropped with 1 to 7 rows of groundnut or pearl millet was on par with the sole crop in the second year (Table 1). It reduced significantly in castor spaced at 60 x 40 cm and intercropped with 1 row of groundnut. The extremely narrow and wide row spacings of castor spaced at 60 x 40 cm intercropped with 1 row and 250 x 10 cm intercropped with 7 rows of pearl millet also significant reduction in the plant height. Kumar *et al.* (1995) observed that the intercropping of pearl millet in paired or three rows of castor had no adverse effect on the plant height in years of low precipitation. The number of leaves/plant was severely reduced in different intercropping treatments during the first year. The planting geometry of castor at 180 x 13 cm with 5 rows of intercropped groundnut was free of interspecific competition. Castor developed the

number of leaves, leaf area and phytomass/plant were on par with the sole crop during both the years. Among different intercropping treatments in pearl millet, 3 rows intercropped with castor afforded no serious competition. The number of leaves, leaf area and phytomass/plant of castor in this treatment was on par with the sole crop during the two years. The intercropping effects for other treatments recorded irregular trend during the two years mainly due to the variable rainfall distribution pattern. Castor experienced severe moisture deficits from 3 to 25 and 39 to 57 days after sowing in the first year. Hence, the vegetative crop growth was severely affected in different planting geometries intercropped with different rows of groundnut or pearl millet. Dry spells occurred late from 63 to 95 and 105 days after sowing to harvest in the second year. Therefore, the competitive effects on vegetative growth characteristics were relatively less in this year. Gangasaran and Giri (1983) reported that there was no significant reduction in number of leaves/plant of castor by intercropping several legume components. But, Padmavathi and Raghavaiah (2003) reported that castor crop stood the competition with 1 or 2 rows of several grain legumes and vegetable components with no significant reduction in its leaf area and phytomass.

Yield components: The treatment effects on yield components of castor were greatly modified by the rainfall distribution pattern during the two years. The number of spikes/plant was not significantly reduced by intercropping 1 to 6 rows of pearl millet in either of the two years (Table 1). Pearl millet was harvested by 90 days. The primary spikes commenced emerging by 38 days. But, groundnut matured late by 110 days and competed with castor for a longer time. Hence, there was a longer competition time for castor with intercropped groundnut than pearl millet. The treatment effects on length of primary, secondary and tertiary spikes were greatly modified by the rainfall distribution pattern during the two years. The length of primary spikes was severely reduced in different intercropping treatments during the first year. Exceptionally, the length of primary spikes of castor sown with the planting geometry of 180 x 13 cm and intercropped with 5 rows of groundnut were on par with the sole crop. Among pearl millet intercropping treatments, castor spaced at 120 x 20 cm accommodating 3 rows of pearl millet produced spikes of same length as the sole crop. This deleterious effect was mainly due to the limitation of moisture during the critical phase of spike development. This led to severe starvation due to the acute limitation of moisture thereby the nutrients to nourish the crop optimally. But, the good rainfall distribution pattern waved off such a severe competition on the length of primary spikes of castor intercropped with different row proportions except 2 rows of groundnut and 7 rows of pearl millet. The acute scarcity of moisture during the reproductive phase of castor also had severe repercussions on the length of secondary spikes in different intercropping treatments during the first year. The length of secondary spikes of castor intercropped with 5 or 6 rows of groundnut and 1 to 4 rows of pearl millet did not reduce significantly. The length of tertiary spikes was in general free of competition by different intercropping treatments. This is probably due to the late appearance of tertiary spikes in 66 days. However, the intercropped competitive effects were more drastic on the number of capsules developed by primary, secondary and tertiary spikes during the first year (Table 1). Sowing of castor at 180 x 13 cm was the best planting geometry to accommodate 5 rows of groundnut since the number of capsules on primary, secondary and tertiary spikes were on par with the sole crop. Intercropping 3 rows of pearl millet in castor spaced at 120 x 20 cm also had no severe competition to reduce the number of capsules/spike. These treatments could be regarded as the best strategy owing to the stable performance of castor on par with sole crop during both the years with differential rainfall distribution pattern.

The seed yield/plant obtained from the primaries, secondaries and tertiaries recorded an irregular trend in response to different planting geometries and row proportions of intercropped groundnut or pearl millet. But, the yield of these spikes was consistently on par with the sole crop by growing castor at 180 x 13 cm and intercropped with 5 rows of groundnut or 3 rows of pearl millet in castor spaced at 120 x 20 cm. Srilatha *et al.* (2002) reported that the yield components of castor *viz.*, length of spike/plant, number of capsules/spike and seed yield/plant were similar in castor sown at 90 x 20 cm spacing and intercropped with 2 rows of groundnut under rainfed conditions. Similar results were also reported by Jadav *et al.* (2003). They obtained substantial variability in the length of primary, secondary and tertiary spikes/plant, number of capsules/spike by changing the spacings and number of rows of groundnut in intercropping systems.

Grain yield of castor: Sole castor produced 697 and 860 kg/ha during *kharif*, 2001 and 2002 respectively (Table 1). Spacing of castor at 180 x 13 cm to accommodate 5 rows of groundnut was the ideal planting geometry and optimum row proportion of the two crops. Castor intercropped with 5 rows of groundnut yielded 628 kg/ha during the first year. This was on par with the sole crop yield of 697 kg/ha. In the second year, a yield of 807 and 860 kg/ha were realised from these treatments. Pearl millet intercropping severely reduced the yield of castor in the first year. It produced 806 kg/ha seed yield by intercropping 3 rows of pearl millet during the second year. This was on par with the sole crop yield of 860 kg/ha. This treatment was less competitive in the first year. In consonance with the changing response to a change in planting geometry Al-Bakry and Saran (1985) observed that groundnut intercropped with 1, 2 or 3 row ratios significantly reduced the yield of castor. Similar observations were made by

Table 1 Influence of intercropping treatments on vegetative growth and yield of castor

Treatment	*Plant height* (cm)		*No. of* leaves		*Leaf area/* plant (cm^2)		*Phytomass/* plant (g)		Length of spike/plant (cm)					
									Kharif, 2001			*Kharif*, 2002		
	2001	2002	2001	2002	2001	2002	2001	2002	*Primary*	Secondary	Tertiary	Primary	Secondary	*Tertiary*
Castor (60x40 cm) + 1 row groundnut	110	104	11	10	4191	4272	155	142	32	31	24	28	28	22
Castor (90x27 cm) + 2 rows groundnut	111	107	11	10	4237	4268	162	143	33	32	26	25	24	14
Castor (120x20 cm)+ 3 rows groundnut	113	114	12	11	4254	4298	164	147	33	33	26	28	30	20
Castor (150 x 16 cm) + 4 rows groundnut	116	109	12	12	4291	4391	163	148	34	34	26	29	28	20
Castor (180 x 13 cm) + 5 rows groundnut	123	116	14	13	4369	4481	169	153	38	38	29	29	30	21
Castor (210 x 11 cm) + 6 rows groundnut	116	109	12	12	4281	4314	166	147	36	35	26	29	29	22
Castor (240x10 cm) + 7 rows groundnut	110	114	11	11	4134	4230	158	139	36	32	25	29	30	21
Castor (60x40 cm) + 1 row pearl millet	106	116	11	12	4151	4270	158	141	37	37	26	26	29	21
Castor (90x27 cm) + 2 rows pearl millet	119	116	12	12	4269	4316	163	144	37	38	27	30	28	15
Castor (120x20 cm)+ 3 rows pearl millet	121	120	13	11	4342	4406	169	154	39	39	29	31	31	22
Castor (150 x 16 cm) + 4 rows pearl millet	113	115	12	10	4289	4322	164	141	36	35	26	28	27	15
Castor (180 x 13 cm) + 5 rows pearl millet	111	114	11	10	4280	4285	164	139	36	33	25	28	28	20
Castor (210 x 11 cm) + 6 rows pearl millet	112	111	11	10	4193	4215	161	133	34	31	24	28	30	21
Castor (240x10 cm) + 7 rows pearl millet	100	104	10	10	4097	4144	157	130	31	29	22	24	24	14
Sole castor (90 x 27 cm)	121	112	13	11	4351	4421	170	156	39	37	29	30	30	16
SEm±	3.7	2.9	0.4	0.5	31	27	1.3	4.7	0.8	1.0	1.2	1.1	1.2	3.6
CD (P=0.05)	11.2	8.7	1.2	1.6	92	78	3.8	14.2	2.5	3.0	3.6	3.3	3.5	NS

NS = Non-significant

Table 1 Contd....

Treatment	*Kharif*, 2001			*Kharif*, 2002			Seed yield/plant (g)								Seed yield (kg/ha)		
	No. of capsules/ spike			No. of capsules/ spike			*Kharif*, 2001				*Kharif*, 2002						
	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary	Total	*Kharif*, 2001	*Kharif*, 2002	Mean
Castor (60x40 cm) + 1 row groundnut	25	26	18	27	21	16	21	18	16	55	25	25	23	73	479	640	559
Castor (90x27 cm) + 2 rows groundnut	26	27	18	27	21	14	23	19	17	59	26	24	15	65	484	506	495
Castor (120x20 cm)+ 3 rows groundnut	27	26	18	30	23	19	23	19	18	60	25	25	23	73	507	662	585
Castor (150 x 16 cm) + 4 rows groundnut	26	27	19	32	24	19	22	19	18	59	25	25	24	74	517	674	595
Castor (180 x 13 cm) + 5 rows groundnut	31	31	24	32	25	21	24	20	19	63	26	26	24	76	628	807	718
Castor (210 x 11 cm) + 6 rows groundnut	30	26	20	32	26	19	22	19	18	59	25	25	23	73	572	452	512
Castor (240x10 cm) + 7 rows groundnut	29	27	19	31	24	20	22	19	17	58	25	25	22	72	531	375	453
Castor (60x40 cm) + 1 row pearl millet	27	27	18	27	24	18	23	19	18	60	25	25	21	71	536	640	588
Castor (90x27 cm) + 2 rows pearl millet	29	28	20	28	22	14	23	19	18	60	26	25	16	67	550	735	643
Castor (120x20 cm)+ 3 rows pearl millet	31	30	25	30	25	20	24	20	19	63	26	26	23	75	601	806	704
Castor (150 x 16 cm) + 4 rows pearl millet	30	26	19	27	22	13	23	19	18	60	26	25	14	65	535	424	480
Castor (180 x 13 cm) + 5 rows pearl millet	29	28	19	26	22	16	21	19	17	57	25	25	20	70	455	400	423
Castor (210 x 11 cm) + 6 rows pearl millet	28	26	18	27	23	17	22	19	17	58	25	25	20	70	403	315	359
Castor (240x10 cm) + 7 rows pearl millet	25	24	18	24	19	13	20	19	16	55	25	24	12	61	352	263	307
Sole castor (90 x 27 cm)	31	31	24	30	23	16	24	20	19	63	26	27	14	67	697	860	778
SEm±	0.6	1.0	1.0	0.9	1.0	2.5	0.5	0.2	0.3	0.8	0.2	0.4	4.5	0.8	23	73	15
CD (P=0.05)	1.7	3.0	3.0	2.6	3.0	NS	1.5	0.7	1.0	2.2	0.7	1.3	NS	2.4	69	219	43

NS = Non-significant

Guggari *et al.* (1994); Srilatha *et al.* (2002). The yield of castor was drastically reduced by intercropping 3, 4 or 5 rows of groundnut. Kumar *et al.* (1995) recorded a significant reduction in seed yield of castor intercropped with pearl millet consistently in two years.

The study indicated that the planting geometry of castor and intercropping row proportions of groundnut or pearl millet influence the crop growth, yield components and yield of castor depending on the rainfall variability during different phases of crop growth. Its yield is best exploited with no severe losses by growing castor at a spacing of 180 x 13 cm with 5 rows of groundnut or altering with planting geometry of 120 x 20 cm with 3 rows of pearl millet under extremely variable rainfall distribution pattern.

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Integrated nutrient management for greengram, *Vigna radiata* (L.) Wilczek - safflower, *Carthamus tinctorius* L. cropping systems under rainfed conditions

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Abstract

On-farm experiments conducted during 2000-01 through 2002-03 to study different nutrient management practices for improving safflower productivity in vertisols showed that economics of safflower in terms of net returns, B:C ratio and total net returns from greengram-safflower system was higher over farmer's practice. During second year, application of 75% RDF to safflower+incorporation of greengram stalk along with soil moisture conservation measures gave significantly higher seed yield of safflower and also net returns of the system which was further confirmed during third year of experimentation. On the basis of pooled data, it may be inferred that application of 75% RDF (30:15 kg NP/ha) + incorporation of greengram stalk after picking pods in *kharif* season and adoption of soil moisture conservation measures were recommended for getting significantly higher seed yield, yield components of safflower as well as net returns from greengram-safflower system under rainfed condition. Final soil analysis indicated that there was slight improvement in organic carbon and decrease in soil pH from 8.12 to 7.61.

Key words: Integrated nutrient management, stalk incorporation, moisture conservation

Introduction

Most of the farmers in drylands are not having easy access for inputs, specially for nitrogenous fertilizers, due to poor resource base and resorting to improper management practices resulting in low efficiency of applied fertilizers. The soils are also low in organic matter, which decreases microbial activity and inhibiting the release of native nutrients and soil moisture stress at critical growth stages of crop, ultimately affecting the crop productivity.

Continuous application of high doses of inorganic fertilizers has been reported to have deleterious effect leading to decline in productivity due to limitation of one or more of micronutrients. Organic recycling has assumed higher importance in the context of cropping systems. Residual nature of organic sources makes them more value based for the whole system compared to individual crops. Recycling of organic matter and use of their moderate doses may also bring down the mounting pressure on use of inorganic fertilizers substantially.

Greengram-safflower is the most popular, remunerative and widely adopted cropping system under rainfed conditions of Maharashtra in general and Marathwada in particular. There is an emerging need to develop low cost nutrient management technology to boost oilseed production on sustainable basis by using locally available organic materials, besides inorganic sources adopting soil and water conservation measures on a cropping system basis. Hence, a field experiment was carried out for investigating the role of locally available organic materials on modifying the nutrient requirements of rainfed safflower based cropping system and to study the nutrient management practices for enhancing productivity.

Material and methods

Ten on-farm trials in first year and 13 each in second and third year were conducted on farmers' fields of watershed area during the year 2000 through 2003. The soils of the experiment field were low in organic carbon (0.5%), available nitrogen (117.2 kg/ha), medium in phosphorus (17.4 kg/ha), high in potassium (745 kg/ha) and slightly alkaline in nature (pH 8.2). There were six treatments in first year which were modified in second and third year of experimentation.

Greengram, cv. Kopergaon was grown during *kharif* season with all recommended cultural practices. Treatments were applied to succeeding crop of safflower. The trials were conducted on farmers' fields with 540 m^2 area/treatment under rainfed conditions. Safflower cv. Sharda was sown in October during *rabi* season. The recommended doses of fertilizers applied to greengram and safflower were 25 : 50 : 0 and 40 : 20 : 0 kg NPK/ha, respectively.

During first year, two sources of organic matter *viz.*, FYM @ 2 t/ha and greengram stalks incorporation along with 100% RDF (40:20 kg NP/ha) and 75% RDF were tested and compared with farmer's practice (50% RDF) and control. After picking of greengram pods, the stalks were incorporated into the soil through harrowing in the respective treatments. In second year, in lieu of FYM one

treatment of soil moisture conservation practice (SMCP) was included. Greengram was grown as per recommendation in *kharif* season and all treatments were applied to safflower (Table 1). The soil moisture conservation measure comprised summer ploughing and intercultivation with blade harrow for making small furrows in standing crop of safflower. Each farmer was treated as a replication and Randomized Block Design was adopted.

Prior to sowing of safflower, treatment-wise soil samples were taken from 30 cm depth and analyzed for various chemical properties and available nutrients. The initial nutrient status of soil regarding available nitrogen was low (117.2 kg/ha), medium in phosphorus (17.4 kg/ha) and high in potassium (745 kg/ha). Observations on yield traits were recorded at 30 DAS, at 50% flowering and at harvest (Table 4). Post-harvest observations included drymatter, number of capitula, number of seeds/capitulum, seed yield/plant and seed yield/ha. Greengram crop was harvested in September and safflower during March in all the three years of experimentation. Spraying of dimethoate, endosulphan and Dithane M-45 was done for the control of aphids and *Alternaria* in safflower. The economics of cropping system was calculated. Pooled analysis of seed yield and total net returns of the system for two years was also done.

Results and discussion

In first year (2000-01), the seed yield of greengram was low due to heavy rainfall at flowering time. The safflower yields were also affected due to inadequate rainfall during *rabi* season. During second year, greengram yields were low due to moisture stress at the time of flowering and seed development stage. Safflower yields were normal during second and third year of experimentation under rainfed conditions.

Application of 100% RDF + FYM @ 2 t/ha to safflower crop recorded significantly higher seed yield (958 kg/ha) followed by incorporation of greengram stalk + 100% RDF to safflower (918 kg/ha). Economics of safflower revealed that net return (Rs. 4253/ha) and B:C ratio (1.85) was higher due to incorporation of greengram stalk, indicating the beneficial effect of *in situ* incorporation of stalk after picking pods. Total net returns of greengram-safflower cropping system (Rs. 5324/ha) was highest with incorporation of greengram stalk + 100% RDF to safflower during 2000-01 (Table 1).

During second year, application of 75% RDF to safflower + incorporation of greengram stalk + soil moisture conservation gave significantly higher seed yield of safflower (1438 kg/ha) and total net returns of the system (Rs. 9438/ha). These results were further confirmed during third year of experimentation where application of 75% RDF + incorporation of greengram stalk + soil moisture conservations has given significantly superior yield (1273 kg/ha) over farmer's practice and was at par with 100% RDF + SMCM.

All the yield contributing characters like number of branches/plant, drymatter, capitula/plant, seeds/capitulum and weight of seeds/plant were more in improved practice than farmer's practice. But, treatment effect on oil content of safflower was not evident (Table 4).

Table 1 Seed yield and economics of greengram-safflower cropping system in 2000-01

Treatments to safflower	Seed yield (kg/ha)		Net returns (Rs/ha)		Total gross returns (Rs/ha)	Total net returns of system (Rs/ha)	B:C ratio of safflower
	Greengram	Safflower	Greengram	Safflower			
T_1 : *Farmer's practice*	*256*	*729*	*833*	*2945*	*11083*	*3778*	1.66
T_2 : Incorporation + 75% RDF	261	808	896	3444	11953	4341	1.73
T_3 : Incorporation + 100% RDF	273	918	1071	4253	13239	5324	1.85
T_4 : No incorporation + 75% RDF + FYM (2 t/ha)	262	848	911	3296	12372	4207	1.62
T_5 : No incorporation + 100% RDF + FYM (2 t/ha)	271	958	1042	4159	13614	5201	1.75
T_6 : *Control*	*265*	*606*	*954*	*2204*	9971	3159	1.56
SEm±	-	13.41	-	135.43		153.97	0.015
CD (P=0.05)	-	37.18	-	374.79		426.12	0.042

Table 2 Yield and economics of greengram-safflower cropping system (pooled)

Treatments to safflower	Seed yield (kg/ha)					Total net returns of cropping system (Rs/ha)			
	2001-02		2002-03		Weighted pooled mean	2001-02	2002-03	Weighted pooled mean	B:C ratio
	Greengram	Safflower	Greengram	Safflower					
T_1 : Farmer's practice	266	1197	795	995	1159	6854	7914	7038	1.87
T_2 : 100% RDF	269	1286	843	1114	1254	7409	8741	7639	1.89
T_3 : 100% RDF + SMCM	271	1380	871	1173	1341	8439	9642	8647	2.01
T_4 : 75% RDF + SMCM + Incorporation	279	1482	912	1273	1443	9890	11133	10104	2.25
SEm±	-	17	-	38	16.67	191	443	184	-
CD (P=0.05)	-	47	-	106	46.21	*529*	*1225*	*510*	-
			2000-01	**2001-02**	**2002-03**				
Market rate (Rs/q)	Greengram		1453	1774	804				
	Safflower		1010	1070	1152				

Table 3 Soil chemical characteristics and nutrient status at harvest

Treatments to safflower	pH	EC	Organic carbon (%)	Available nutrient (kg/ha)		
				N	P	K
T_1 : Farmer's practice	8.12	0.169	0.48	115.91	14.53	759.13
T_2 : 100% RDF	7.94	0.171	0.51	119.50	15.44	768.47
T_3 : 100% RDF + SMCM	7.93	0.174	0.52	120.61	16.22	771.28
T_4 : 75% RDF + SMCM + incorporation	7.61	0.190	0.55	122.23	16.78	784.29

Table 4 Growth, yield components and oil content as influenced by different treatments (at harvest)

Treatments to safflower	Plant height (cm)	No. of primary branches	No. of leaves/plant	No. of capitula/plant	Drymatter (g/plant)	No. of seeds/capitulum	Weight of seeds/plant (g)	Mean oil content (%)
T_1 : Farmer's practice	86	13	99	19	127	25	35.4	25.3
T_2 : 100% RDF	87	14	102	20	132	29	38.2	25.5
T_3 : 100% RDF + SMCM	89	15	102	21	135	31	39.9	25.6
T_4 : 75% RDF + SMCM + incorporation	90	17	108	24	137	33	41.5	25.7
SEm±	2.5	2.0	3.3	1.7	3.5	1.8	2.1	1.3
CD (P=0.05)	NS	NS	NS	4.71	9.69	4.98	5.82	NS

Similar findings were reported by Rang *et al.* (1985), Hegde (1998), Duhoon *et al.* (2001) and Vani and Bheemaiah (2003).Similarly, total net returns of the system (Rs. 11133/ha) and B:C ratio (2.15) was highest with 75% RDF + incorporation of greengram stalk + soil moisture conservations. Pooled data of 2 years revealed that application of 75% RDF (30:15 kg NP/ha) + incorporation of greengram stalk after picking pods in *kharif* season and adoption of soil moisture conservation measures (summer ploughing + intercultivation with blade hoe) were recommended for getting higher yield of safflower (1443 kg/ha) and total net returns (Rs. 10104/ha) from greengram-safflower cropping system, provided soil moisture was not a limiting factor at the time of incorporation of greengram stalk (Table 2). There was 25% saving in cost of inorganic fertilizer due to *in situ* incorporation of greengram stalk.

Final soil analysis indicated that, there was slight improvement in organic carbon status of soil, decrease in soil pH from 8.12 to 7.61. However, it needs further confirmation (Table 3).

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Probable "Puccinia" path of groundnut rust in northern Karnataka

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Abstract

Rust of groundnut caused by *Puccinia arachidis* Speg has led to severed yield losses in places wherever groundnut is grown. Epidemiological factors coupled with virulence of the pathogen play an important role in disseminating the uredospores from one location to the other. It is evident from the study conducted at Raichur that rust spores and disease appearance were first observed in Raichur during 2002 and 2003. Observations on movement of uredospores of *P. arachidis* revealed that, Raichur acted as a source of inoculum and hot spot of groundnut rust. Based on the trap nursery trial, aeroscope method and weather data, probable path of *P. arachidis* was traced out and concluded that Raichur as one of the hot spot for the out break in northern Karnataka.

Key words: Disease of groundnut, rust, hot spot, uredospores

Introduction

Groundnut rust caused by *Puccinia arachidis* is an economically important disease in northern Karnataka. The losses from 29 to 42% due to rust have been reported (Krishna Prasad *et al.*, 1979; Mallaiah and Rao, 1982; Siddaramaiah, 1983). Further, Benagi (1991) reported that, Raichur is the hot spot for outbreak of rust. Now the disease has become one of the major constraints for groundnut cultivation, particularly in northern Karnataka. Recently, Pande and Narayan Rao (2000) recorded highest severity of 81-90% yield losses due to rust in groundnut. The weather factors play an important role in disseminating the uredospores from one location to another through wind current. However, as a part of epidemiology trapping of uredospores in trap nurseries and catching uredospores by aeroscope method would enable to trace the path of *P. arachidis*. Therefore, in the present investigation, the atmospheric uredospore load of groundnut rust trapped in spore trap and disease appearance in the trap nurseries during *kharif* 2002 and 2003 was studied.

Materials and methods

To trap the uredospores of *P. arachidis* during *kharif* 2002 and 2003 an aeroscope for exposure of stationary slides was mounted at a height of 1.5 m during the cropping seasons in the field of Regional Agricultural Research Station Farm, Raichur. The slides which were thinly smeared with vaseline were used for trapping the uredospores. The slides were removed every day at 8.30 h. Average number of uredospores per microscopic field was recorded under low power objective (10x) by taking count of ten microscopic fields in each slide.

Appearance of disease on groundnut crop in the aeroscope installed field was recorded. Observations were made daily to record the first appearance of the disease in the field.

Trap nursery trial: A trap nursery consisting of six varieties *viz.*, JL-24, DH-86, R-8808, GPBD-4, K-134 and DH-53 was planted during *kharif*, 2002 and 2003 at Regional Agricultural Research Station (RARS), Raichur, Agricultural Research Station (RRS), Gulbargba; ARS, Gangavati; RARS, Bijapur; ARS, Hagari; ARS, Bidar; ARS, Annigeri; Main Agricultural Research Station (MARS), Dharwad and ARS, Arabhavi in non-replicated trials to trace the movement of uredospores of *P. arachnids* and also occurrence of disease. Based on the data collected pertaining to appearance of disease in trap nurseries at different locations during both the years 2002 and 2003, possibly pathway of movement of uredospores of *P. arachidis* was made out.

Results and Discussion

The deposition of uredospores on glass slide of the aeroscope in the groundnut field commenced in first week of August before onset of disease in the trap crops during 2002 and 2003 at Raichur. Higher number of uredospores/microscopic field were observed during August and September and the rust severity at this period was more on the crop at all the locations.

The disease appearance was first noticed in Raichur on 5th August, 2002 followed by Gangavati and Gulbarga on 10th September, 2002, Bijapur (12.09.2002), Hagari (17.09.2002), Bidar (18.09.2002), Annigeri (20.09.2002), Dharwad (22.09.2002) and Arabhavi (28.09.2002) during 2002.

During 2003, the appearance of disease followed same trend as observed during 2002. The disease was first noticed in Raichur (08.08.2003), Gangavati (24.08.2003),

Gulbarga (06.09.2003), Bijapur (10.09.2003), Hagari (12.09.2003), Bidar (14.09.2002), Annigeri (15.09.2003), Dharwad (20.09.2002) and Arabhavi (22.09.2002).

This confirmed that Raichur acted as a source of inoculum and hot spot of groundnut rust. This might be due to favourable weather factors like moderate temperature (25-31°C), higher relative humidity (83-91%) and intermittent rainfall. This finding was strongly supported by Benagi (1991) who opined that Raichur is the hot spot for outbreak of rust.

During 2002, the disease spread from Raichur to Gangavati and Gulbarga directly, subsequently the disease was observed in Bijapur followed by Hagari, Bidar, Annigeri, Dharwad and Arabhavi. On the other hand, during 2003, the disease outbreak observed first at Raichur, then spread to Gangavati and subsequently appeared in Gulbarga, Bijapur, Hagari, Bidar, Annigeri, Dharwad and Arabhavi. Thus, the observations revealed that Raichur as one of the foci of infection which helps in further spread of the disease and makes a way to conclude that, uredospores of *P. arachidis* probably traveled along with the wind current in south or south western direction from Raichur.

The study conducted during 2002 and 2003 thus confirmed that, Raichur acted as a source of inoculum and hot spot of groundnut rust. This finding was strongly supported by Benagi (1991) who opined that Raichur serves as hot spot for *P. arachidis*. Thus, based on the above information, the possible movement of uredospores of *P. arachidis* was traced and depicted in Fig. 1 and 2 during 2002 and 2003, respectively.

The variation in disease appearance in different localities may also be attributed to the prevalence of favourable weather conditions. Earlier, Mallaiah and Rao (1982 and 1987) reported that air dispersed the uredospores of rust very effectively.

At Raichur, first catch of spore was recorded on 30.07.2002 and 25.07.2003 for 2002 and 2003, respectively, wherein weather conditions during the previous week were temperature (max) (35.1-36.9°C), temperature (min) (23.0-24.2°C) coupled with RH (%).

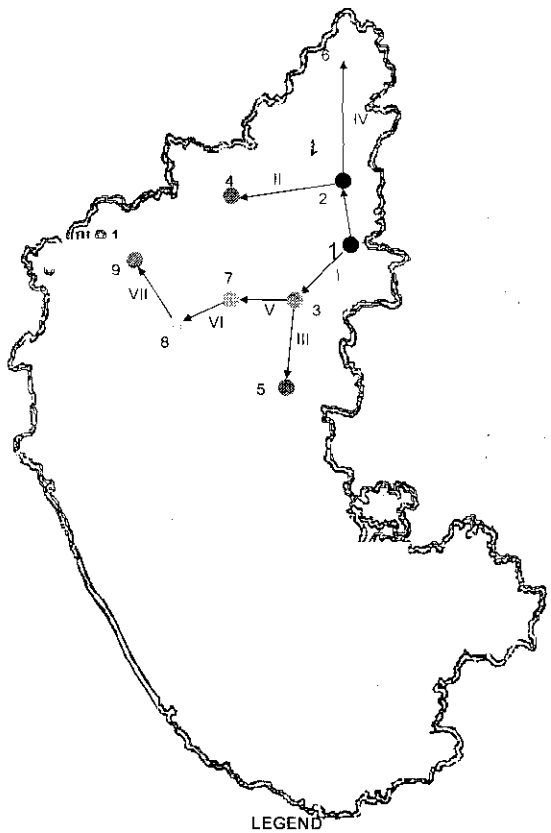

Fig. 1. Probable pathway of *P. arachidis* in northern Karnataka during *kharif* 2002

(Thakur *et al.*, 2000) for the rainy 2002 derived material. Yield components namely pod yield (g/plant), shelling out-turn (%) and test weight (g/100 seeds) were assessed for these lines over two seasons *viz.*, rainy and post-rainy, 2002.

Results and discussion

Pooled analysis of variance for two seasons (rainy and post-rainy, 2002) revealed significant differences between genotypes for yield components namely, pod yield, shelling out-turn and test weight (Table 1). Significant seasonal influence was noticed for test weight, while significant interaction between season and genotype was noticed for pod yield and test weight (Table 1). Genotypes showed significant differences for reaction to LLS, rust and *in vitro* seed colonization by *Aspergillus flavus* (Table 2).

Among the parents/checks, TAG 24 recorded highest pod yield followed by TG 49 and R9227 (Table 3). Most of them showed high shelling out-turn except Mutant 28-2. B37c and GPBD 4 showed resistance to LLS and rust; R 9227 showed moderate resistance to LLS, rust and *Aspergillus*; Mutant 28-2 showed resistance to LLS and moderate resistance to rust and *Aspergillus* and TG49 showed resistance to *Aspergillus* (Table 3). As observed in the present study, interspecific derivatives (GPBD 4, B 37c and R 9227) and mutants (Mutant 28-2) are the potential sources of resistance to diseases.

As reported by Hegde *et al.* (1995), most of the resistant sources are either *Valencia land races or interspecific* derivatives with many undesirable attributes like late maturity, thick shell, low productivity and poor adaptation making them unsuitable for direct utilization. Hence, crosses were made between Trombay groundnuts (TAG 24, TG 26 and TG 49) and resistant sources (GPBD 4, Mutant 28-2, B37c and R 9227) to develop multiple disease resistant confectionary lines. Among the 57 advanced breeding lines evaluated, several lines showed resistance (≤4 score to LLS and rust; <2 score to *Aspergillus*) / moderate resistance (4-6 score to LLS and rust; 2-3 score to *Aspergillus*) to one or more diseases by retaining desired yield. Among these lines, 12 lines showed resistance/moderate resistance to only LLS; 1 line to only rust, 6 lines to only *Aspergillus*, 16 lines to LLS and rust, 8 lines to LLS and *Aspergillus*, 1 line to rust and *Aspergillus*, 3 lines to LLS, rust and *Aspergillus* (Table 4).

Thirteen out of 57 lines out-yielded the best check TAG 24 for pod yield while 21 lines out-yielded TG 49 (Table 3). Some of these lines also combined resistance to diseases, *viz.*, TG 49 x GPBD4, 2b (LLS, rust and *Aspergillus*); TG 26 x Mutant 28-2, 119-1 and TG 49 x Mutant 28-2, 28-1 (LLS and rust); TG 49 x R 9227, 13 (i) (LLS and *Aspergillus*); TG 49 x Mutant 28-2, 69-1 and TG 49 x Mutant 28-2, 2-2 (only LLS); TG 49 x R 9227, 8 and R 9227 x TG 49, 27-1 (only *Aspergillus*) besides retaining higher yield and desired test weight (Table3). Four lines showed higher shelling out-turn than the best check TAG 24, while 22 lines showed higher shelling out-turn than TG 49. Nine lines recorded higher test weight than the best check TG 49 (Table 3). Several lines were superior than TG 49 besides combining resistance to one or more diseases (Table 4).

Table 1 Pooled analysis of variance (mean sum of squares) for yield components in confectionary lines over two seasons (rainy and post-rainy, 2002)

Source of variation	Degrees of freedom	Pod yield (g/plant)	Shelling out-turn (%)	Test weight (g)
Season	1	40.7	26.5	4062.0**
Replication	1	53.7	20.1	75.8
Season x Replication	1	123.1	0.0	146.9
Genotypes	63	113.4**	41.5**	297.3**
Season x Genotypes	63	75.6**	28.0	101.5**
Error	126	40.2	26.2	55.5

Table 2 Mean sum of squares for resistance to major diseases in confectionary lines

Source of variation	degrees of freedom	Late leaf spot (rainy, 2002)	Rust (rainy, 2002)	*Aspergillus* (*in vitro*)
Replication	1	5.7	7.5	0.0004
Genotypes	63	4.6**	3.7**	1.0**
Error	63	0.6	0.5	0.0008

Table 3 Mean performance of superior confectionary lines and parents/checks over two seasons (rainy and post-rainy, 2002)

Genotypes	LLS ®-02)	RUST (R-02)	ASP (*in vitro*)	PY (g/plant) (R-02&PR-02)	SO (%) (R-02&PR-02)	TW (g) (R-02&PR-02)
TG49 x B37c, 84	5.5*	5.5*	3.03	19.7	65.7	50.1
TG49 x B37c, 90	5.5*	7.5	2.07*	19.4	67.4	61.2
TG49 x B37c, 91	6.0*	7.5	2.89*	17.7	73.9*	69.0*
TG49 x B37c, 107	7.0	4.5*	2.24*	22.3	65.7	67.1*
TG49 x B37c, 141-2	6.0	7.5	3.50	18.9	72.4*	51.6
TG49 x B37c, 12	4.8*	4.5*	3.32	21.8	73.7*	58.0
TG49 x B37c, 17-1	5.5*	5.0*	3.98	22.2	66.7	60.5
TG49 x B37c, 49-2	7.0	4.5*	3.60	24.5*	72.2*	51.0
TG49 x B37c, 72-1b	4.5*	4.5*	2.00*	24.3*	70.9*	60.4
TG49 x B37c, 74-2	4.5*	4.5*	3.99	23.4*	66.9	50.8
TG49 x B37c, 97-1	6.8	7.0	1.88*	20.7	70.2*	60.3
TG49 x B37c, 99 b	4.5*	7.0	2.68*	23.9*	78.5*	50.2
GPBD4 x TG49, 8	2.5*	6.5	3.34	17.8	67.2	70.2*
GPBD4 x TG49, 77	4.0*	3.5*	3.91	17.9	70.1*	57.6
GPBD4 x TG49, 81-1	3.0*	3.5*	3.95	19.6	66.5	51.0
GPBD4 x TG49, 126	4.5*	4.5*	4.00	22.9*	66.4	55.2
GPBD4 x TG49, 147-1	5.5*	5.5*	3.22	20.4	68.3	57.2
GPBD4 x TG49, 169	4.0*	4.0*	4.00	24.2*	73.3*	57.8
GPBD4 x TG49, iii-8	5.0*	4.0*	2.95*	14.8	66.4	54.8
TG49 x GPBD4, 20-2	6.0*	4.0*	3.05	21.3	72.2*	61.7
TG49 x GPBD4, 21-2	3.5*	7.0	3.21	25.6*	62.6	63.9
TG49 x GPBD4, 2 b	3.0*	2.0*	2.83*	32.3*	71.3*	52.3
TG49 x GPBD4, 8	4.0*	4.5*	3.54	20.9	72.1*	55.9
TG49 x GPBD4, 16-1	3.5*	7.0	2.99*	22.1	72.2*	54.8
TG49 x Mutant 28-2, 2-2	3.0*	6.5	3.97	27.8*	70.4*	59.5
TG49 x Mutant 28-2, 16	3.0*	6.5	3.86	21.8	69.4	63.9
TG49 x Mutant 28-2, 28-1	2.0*	6.0*	3.58	27.2*	68.4	67.4*
TG49 x Mutant 28-2, 1-1	3.0*	6.5	3.93	26.4*	68.3	50.2
TG49 x Mutant 28-2, 69-1	3.0*	6.5	3.95	29.3*	68.2	55.1
TG49 x R9227, 8	6.5	7.0	1.58*	30.5*	67.1	63.6
TG49 x R9227, 13	6.5	7.0	1.79*	22.5*	72.0*	65.4*
TG49 x R9227, 19	5.5*	6.5	2.07*	20.9	70.5*	65.2*
TG49 x R9227, 13(I)	6.0*	6.5	2.85*	29.7*	73.8*	74.0*
R9227 x TG49, 16	7.0	7.0	2.91*	22.7*	74.5*	51.6
R9227 x TG49, 12	6.0*	7.0	1.49*	24.1*	67.1	69.2*
R9227 x TG49, 14	6.5	7.0	2.89*	22.6*	70.7*	69.2*
R9227 x TG49, 20-1	5.5*	6.5	3.24	21.3	70.9*	50.5
R9227 x TG49, 27-1	6.5	7.0	2.08*	27.8*	72.7*	58.9
TG26 x Mutant 28-2, 156-2	4.5*	6.5	3.37	26.4*	72.1*	52.1
TG26 x Mutant 28-2, 119-1	2.0*	5.0*	3.84	30.7*	66.4	54.2
Parents / Checks						
TG 49	5.0*	8.0	1.96*	22.5*	68.5*	64.8*
Mutant 28-2	3.0*	6.0*	2.87*	18.7	65.3	54.2
TAG 24	6.5	8.0	3.58	26.6*	73.8*	52.1
GPBD 4	2.0*	4.0*	3.82	16.4	73.2	44.4
TG 26	5.0*	7.5	3.71	10.5	73.3	47.1
B37c	3.5*	4.0*	3.16	19.0	72.6	55.1
R 9227	5.0*	6.0*	2.75*	21.0	71.9	45.5
CD (P=0.05)	1.5	1.4	0.05	8.9	7.2	10.4
C.V. (%)	15.4	12.2	0.92	28.1	7.3	11.3

R02- rainy 2002, PR02- post-rainy 2002; LLS- Late leafspot, ASP- Aspergillus. PY- Pod yield, SO- Shelling out-turn, TW- test weight

* Indicates resistance (≤4) / moderate resistance (4-6) to LLS and rust; resistance (<2) / moderate resistance (2-3) to Aspergillus; superiority for pod yield / shelling out-turn / test weight

Table 4 Confectionary lines showing resistance to major diseases

Resistant to	Confectionary lines	
LLS	TG49 x B37c, 141-2	TG49 x Mutant 28-2, 69-1
	GPBD4 x TG49, 8	R9227 x TG49, 20-1
	TG49 x GPBD4, 21-2	TG26 x Mutant 28-2, 156-2
	TG49 x Mutant 28-2, 2-2	TG26 x Mutant 28-2, 279
	TG49 x Mutant 28-2, 16	TAG24 x Mutant 28-2, 84
	TG49 x Mutant 28-2, 1-1	TAG24 x Mutant 28-2, 86
Rust	TG49 x B37c, 49-2	
Aspergillus	TG49 x R9227, 8	R9227 x TG49, 16
	TG49 x B37c, 97-1	R9227 x TG49, 27-1
	TG49 x R9227, 13	R9227 x TG49, 14
LLS and Rust	TG49 x B37c, 84	GPBD4 x TG49, 147-1
	TG49 x B37c, 12	GPBD4 x TG49, 169
	TG49 x B37c, 10-1	GPBD4 x TG49, 81-1
	TG49 x B37c, 17-1	TG49 x GPBD4, 20-2
	TG49 x B37c, 74-2	TG49 x GPBD4, 8
	GPBD4 x TG49, 77	TG49 x GPBD4, 10-1
	GPBD4 x TG49, 64-1	TG49 x Mutant 28-2, 28-1
	GPBD4 x TG49, 126	TG26 x Mutant 28-2, 119-1
LLS and *Aspergillus*	TG49 x B37c, 99 b	TG49 x R9227, 37
	TG49 x B37c, 90	TG49 x R9227, 19
	TG49 x B37c, 91	TG49 x R9227, 13 (I)
	TG49 x GPBD4, 16-1	R9227 x TG49, 12
Rust and *Aspergillus*	TG49 x B37c, 107	
LLS, Rust and *Aspergillus*	TG49 x B37c, 72-1b	
	GPBD4 x TG49, iii-8	
	TG49 x GPBD4, 2 b	

The results of the present study indicated that it is possible to incorporate resistance into good agronomic types by hybridization with resistant sources followed by selection. Gowda *et al.* (1996) also reported that the multiple crosses between interspecific derivatives and high productivity lines tended to combine good agronomic features with moderate level of resistance, while resistant types suffered from low shelling out-turn, undesirable pod features besides late maturity. For the last four decades, genetic improvement of groundnut by induced mutation and recombination breeding at BARC, Trombay has led to isolation of 61 distinct genotypes, of which 8 have been released for commercial cultivation (Badigannavar *et al.*, 2002). Response to family selection was found to be superior compared to single plant selection for all disease resistance parameters, pod features and productivity parameters (Bhat *et al.*, 1985), while three-way crosses were found superior compared to single crosses in yielding better segregants for resistance along with desirable agronomic attributes (Sheshagiri, 2000). Though several difficulties have been reported by earlier workers as noted above, it was possible in the present study to develop agronomically superior lines combined with resistance to multiple diseases in confectionary types of groundnut. Similarly, Manivel *et al.* (2002) isolated an advanced breeding culture, PBS 23007 resistant to early leaf spot, late leaf spot and rust from a cross between GG 11, a popular Virginia cultivar and NC Ac 2230, a mutant line with resistance. The most potential lines are in advanced trials for adoption to commercial cultivation.

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Variability in *Aspergillus flavus* L. Ex. Fries infecting groundnut, *Arachis hypogaea* L.

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Abstract

Aflatoxins are produced in groundnut (*Arachis hypogaea* L.) seed due to infection of *Aspergillus flavus* L. Ex. Fries. Incidence of *A. flavus* was recorded maximum in Belligatti (75%) on agar plate. In blotter technique it was maximum in Davanagere and Tumkur (20%). Maximum toxin production was in Shimoga isolate (2347 µ/kg) and minimum in Mudhol isolate (16.6 µ/kg) in groundnut kernel. In isozyme studies, isolate showed narrow variability in rf values for peroxidase and polyphenol oxidase (0.2-0.3).

Key words: *Aspergillus flavus*, Aflatoxin, groundnut

Introduction

Aspergillus flavus L. Ex. Fries contaminated groundnut and its products are health hazardous to human beings and livestock. The aflatoxins produced by it in groundnuts are regarded as potent carcinogens causing liver cancer and many other disorders. Their harmful effects includes tetragenecity, deformation of developing foetus (Dipaolu *et al.*, 1967), reduction in RBC, WBC and hemoglobin content in blood and delayed blood clotting and suppression of immune system in case of chronic poisoning (Clark *et al.*, 1986). Due to food safety problems posed by aflatoxins, food and drug administration USA has set level of 20 ppb for total aflatoxins in domestic human foods. However, the European Union (EU) has reset the standards for aflatoxin tolerance at 2 ppb for aflatoxin B1 and 4 ppb for total aflatoxin in human diet with effect from 1999 (Tushar Tanna, 2002).

In order to initiate an effective programme on management of *A. flavus* infection in groundnut a precise understanding of load of pathogen in groundnut produce and its morphology, cultural characters and physiology traits is utmost important. In addition, pathogenic variability of *A. flavus* was also constituted in the present study. All the commercial cultivars presently grown in India are susceptible to *A. flavus*. Nevertheless, it was felt necessary to subject some of the selected and newly bred groundnut genotypes for test verification at the location to know their reactions to the pathogen. Hence, there is an urgent need to undertake screening of larger number of genotypes to search for resistance to *A. flavus*.

Materials and methods

The present investigations were carried out at Plant Pathology Laboratory, Oilseeds Scheme, University of Agricultural Sciences, Dharwad during 2004 and 2005.

Survey, collection of samples and isolation of fungus: An intensive survey was conducted during January-April, 2004 to know the incidence and severity of *A. flavus* infection in groundnut in Karnataka. Farmers fields in Dharwad, Belgaum, Raichur, Gulbarga, Bidar, Bagalkot, Haveri, Uttar Kannada, Bangalore, Davanagere, Shimoga and Tumkur districts were selected to collect samples. Samples were also taken from markets of Dharwad, Belgaum and Bangalore. The samples (pod) were dried in sunlight for 2-3 days and stored in gunny bags and used for assessment immediately.

The apparently healthy seeds were surface sterilized in 0.1% mercury chloride ($HgCl_2$) solution for one minute and washed thoroughly in distilled water and then transferred to sterile PDA plates and also on to blotters and incubated. The seeds yielding *A. flavus* and other fungi were enumerated and per cent incidence was calculated. The location specific *A. flavus* isolates obtained were further studied for their morphological characters and compared with description of Thom and Raper (1945).

Detection of toxigenic isolate of *A. flavus* : Seeds of JL-24 obtained from All India Co-ordinated Research Project on Groundnut, Dharwad centre were subjected to assessment using ELISA method.

Apparently healthy and good seeds of uniform size and shape with intact testa were taken in 5 g of seed lots for treating with each isolates of *A. flavus*. These seeds were surface sterilized in mercuric chloride followed by three rinses in distilled water. Each seed lot was placed aseptically in sterile 90 mm diameter Petri dishes and one ml spore suspension of respective isolate was spread over the seeds by gently whirling them around within the dish. The plates were placed in incubator at 25°C and 98±2% relative humidity for eight days. The seeds were taken out, washed in tap water and fungal growth was removed. The seeds were ground in 70% methanol (v/v 70 ml of absolute methanol in 30 ml of distilled water) containing 0.5% KCl (@ 5 ml for one g of seed) in a blender for two minutes. The extract was transferred to conical flask and shaked for

30 minutes at 300 rpm. The extract was filtered through Whatman No. 41 and diluted 1:10 PBS-Tween and stored in refrigerator at 4°C. The same procedure was repeated for 5 ml culture filtrate of 22 isolates grown on potato dextrose broth (for 10 days). The samples were estimated for afla toxin B1 through ELISA at plant pathology, Legume programme at ICRISAT, Patancheru, Hyderabad.

Isozyme studies : Isoezyme variation among the isolates of *A. flavus* infecting groundnut was investigated by adopting the vertical polyacrylamide gel electrophoresis (PAGE) method (Sadasivam and Manikam 1992).

Forty ml of 10% gel mixture was prepared by mixing following solution. Acrylamide solution (A) (13.3 ml), Tris-HCl (pH 8.8) (B) (8.0 ml), Ammonium persulphate (C) (0.2 ml), TEMED (D) (20.0 ml) and Distilled water (18.0 ml)

The solutions were mixed gently and carefully and poured in the chamber between glass plates. Top portion of plates were covered with thin layer of water to hasten the process of polymerization since oxygen affects the process of polymerization. The gel was allowed to set for 60 min. After polymerization gel combination was removed without disturbing shape of the well. The adhesive, top and bottom spacers were removed and gel was installed in electrophoresis unit in its proper position. Both tanks of the unit were filled with electrode buffer and air bubbles at the bottom of gel were removed. Then sample was loaded gently and carefully into sample well @ 50 µl/well with the help of micropipette, 25 µl of 0.001% of bromophenol blue was placed in one of the wells as tracking dye. Electrodes were placed in tank buffer in their proper position and connected to AC power through power pack apparatus. The gel was run at 30 mA for 5 hours at 5°C. After the run, gel was removed and distance traveled by the dye was measured and recorded. The gel was incubated in enzyme specific stain for specific period of time. The rf values of peroxidase and polyphenol oxidase isozymes were calculated for each isolate.

Screening : Apparently healthy seeds of 15 genotypes obtained from the All India Co-ordinated Research Project on Groundnut, Dharwad centre, were subjected to assessment using seed colonization technique (Ghewande *et al.*, 1993).

Apparently healthy seeds of uniform size and shape with intact testa were taken in approximately 20 g of seed lots with three replications. The seeds were surface sterilized separately by soaking them for two min in 0.1% aqueous solutions of mercuric chloride. This was followed by four rinses in sterile distilled water. The seeds were then hydrated to approximately 20% moisture content by soaking them for ten min. The seeds were then placed aseptically in a sterile 90 mm Petridish and one ml of spore suspension was spread over the seeds by gently whirling them around within the dish. For preparation of inoculums, culture of eight days old was flooded with sterile distilled water containing five per cent Tween 20 (v/v) and spores were detached from cultures and removed in the suspension, which was later adjusted to contain 4.0×10^6 conidia/ml. Then plates were placed over water in semi-rigid plastic boxes which had tight fitting lids and were then placed in an incubator at 25°C and 98±2% relative humidity for eight days. After incubation, observation on seed invasion and colonization by *A. flavus* were recorded Ghewande *et al.* (1993).

Results and discussion

Survey, collection of samples and isolation of fungus : The results of agar plate and blotter revealed that abundance of *A. flavus* incidence was varied from location to location. It ranged from traces to 25% in agar plate method and 3-20% in blotter technique. In case of field samples, maximum fungal incidence was recorded in Belligatti (25%) in agar plate. On other hand, Davanagere and Tumkur samples recorded maximum colonies of *A. flavus* (20%) in blotter technique. Among market samples, maximum fungal incidence was recorded in samples of Dharwad (25%) and Hubli (16.6%), on agar plate and blotter technique, respectively. Higher incidence of fungi in fields of Dharwad and Dharwad market during January to April months of 2004 may be attributed to prevalence of favourable conditions like prolonged drought, optimum temperature (27-30°C), relative humidity and moisture content of pods that might have helped the infection of *A. flavus* to groundnut. Therefore, samples yielded high proportion of *A. flavus* (Table 1).

Detection of toxigenic isolates of *A. flavus* : While testing for aflatoxin level, all the isolates turned out to be toxigenic, maximum production of toxin was recorded in Shimoga isolate (2347.7µg/kg) followed by Ranebennur isolate (1819.7 µg/kg). In cultural filtrate obtained from cultural medium, the isolates also produced maximum toxin. The Shimoga isolate (2228.5 µg/kg) and Dharwad campus isolate (17.9 µg/kg) were exhibited maximum and minimum toxin production, respectively. The study revealed that isolates varied for aflatoxin production both in kernel extract and culture filtrate. Further, aflatoxin-producing ability is often variable and ability to produce aflatoxin is not uniform among strains (Suman Mor and Singh, 2000) (Table 2).

Isozyme studies: The isozyme analysis revealed that all the isolates exhibited single band with rf value 0.9 for peroxidase. Based on rf value, all the 22 isolates under study are exhibited narrow variability. The polyphenol oxidase analysis revealed that isolates ranged between 0.2 to 0.3, based on this rf value isolates found to possess certain variability (Table 2). The study revealed that isolates were closely related to each other based on zygogramme patterns.

Table 1 Composition of seed mycoflora of groundnut

Location	Association of seed mycoflora of groundnut (%)									
	Agar plate					Blotter technique				
	A. flavus	*A. niger*	*Rhizopus* spp.	*Fusarium* spp.	Others	*A. flavus*	*A. niger*	*Rhizopus* spp.	*Fusarium* spp.	Others
Bhalki	-	36.6	23.3	10.0	20.0	13.3	23.3	16.7	-	10.0
Bangalore	20.0	43.3	33.3	3.3	10.0	3.0	26.7	23.3	-	10.0
Dharwad	3.3	56.7	33.3	3.3	13.3	13.3	10.0	23.3	-	6.7
Ranebennur	3.3	60.0	26.7	-	3.3	3.3	13.3	6.6	6.6	23.3
Chitradurga	-	50.0	56.7	-	16.7	16.6	10.2	10.0	-	23.3
Tiptur	-	33.3	26.6	-	13.3	10.0	20.2	26.7	3.3	13.3
Bailhongal	-	36.7	23.3	13.3	20.0	6.7	20.0	30.0	10.0	10.0
Shimoga	6.7	33.3	56.7	10.0	13.3	3.3	20.0	30.0	-	6.7
Bellary	6.7	26.7	56.7	3.3	33.3	13.3	6.6	26.7	-	13.3
Mudhol	-	60.0	26.7	-	16.7	10.0	10.0	10.0	-	23.3
Davanagere	16.6	26.6	26.7	-	10.0	20.0	26.6	13.3	3.3	20.0
Ankola	-	73.3	26.7	-	16.7	10.0	20.0	23.3	-	16.6
Raichur	-	23.3	23.3	6.7	3.3	6.7	13.3	10.0	-	16.7
Belgaum	-	20.0	26.7	23.3	10.0	13.3	13.3	-	3.3	13.3
Tumkur	-	53.3	-	23.3	3.3	20.0	13.3	23.3	-	10.0
Kittur	13.3	33.3	-	-	13.3	3.3	23.3	23.7	3.3	13.3
Manavi	3.3	36.7	-	-	13.3	6.7	13.3	20.0	-	13.3
Belligatti	25.0	40.0	-	-	5.0	3.3	16.6	10.0	-	13.3
Hubli (market)*	-	70.0	26.7	-	16.7	16.6	16.6	13.3	-	6.7
Magdi*	0.4	50.0	26.7	6.7	6.7	10.0	13.3	6.7	3.3	10.0
Dharwad (market)*	25.0	20.0	-	-	-	10.0	16.6	20.0	-	10.0

* Market samples

Table 2 ***Aflatoxin content and isozyme pattern of peroxidase and polyphenol oxidase in groundnut kernels infected with different isolates of Aspergillus flavus***

Location and isolates	Kernel extract (mg/kg)	Culture filtrate (mg/L)	rf value	
			Peroxidase	Polyphenol oxidase
Bhalki (AFL BHL)	838.8	822.6	0.9	0.2
GKVK AFL GKV)	91.7	77.2	0.9	0.2
Dharwad campus (AFL DWC)	18.1	17.9	0.9	0.3
Ranebennur (AFL RBN)	1819.7	1700.7	0.9	0.2
Chitradurga (AFL CDG)	1788.7	1780.1	0.9	0..3
Tiptur (AFL TPR)	1143.4	1133.7	0.9	0.2
Bailhongal (AFL BLG)	78.5	76.1	0.9	0.2
Shimoga (AFL SMG)	2347.7	2228.5	0.9	0.3
Bellary (AFL BLY)	536.2	532.1	0.9	0.2
Hublimarket (AFL HBM)	949.9	946.1	0.9	0.2
Mudhol (AFL MDL)	16.6	15.9	0.9	0.2
Davanagere (AFL DVG)	500.5	498.8	0.9	0.2
Ankola (AFL ALK)	202.4	201.2	0.9	0.2
Raichur (AFL RCR)	431.6	430.3	0.9	0.3
Magadi (AFL MGB)	521.2	521.4	0.9	0.2
Belgaum (AFL BGM)	35.1	34.6	0.9	0.3
Tumkur (AFL TMR)	26.2	260.1	0.9	0.2
Kittur (AFL KTR)	43.4	43.3	0.9	0.3
Manvi (AFL MNV)	830.1	830.2	0.9	0.2
Belligatti (AFL BGT)	33.8	92.2	0.9	0.2
Dharwad market (AFL DWM)	1526.7	1517.2	0.9	0.3
Junagadh (AFL JGR)	1391.2	1388.3	0.9	0.2
Control	5.5	0.0		

Quality studies: Reduction in total sugar, reducing sugar and non-reducing sugar was noticed in inoculated seeds of 15 cultivars. In total sugar, it was to the extent of 0.3 to 7.2% in reducing sugar 0.8 to 9.1% and in case of non-reducing sugar it was from 0.2 to 6.6%. The reason for reduction in sugar might be due to utilization of sugar by fungi (Jamaluddin *et al.*, 1987). Sugar plays a major role for disease resistance in plant and they are also the pre-cursor for synthesis of phenols and phytoalexins. The investigation also revealed that reduction in oil content (2.4%-6.11.0%) in *A. flavus* inoculated seeds compared to apparently healthy ones. While, invading fungus causes the oxidation of fatty acids and inactivation of enzymes. This may be the reason for the reduction in oil content (Foote, 1976; Spike, 1977).

Screening: The results indicated that none of the genotype showed resistant reaction against the pathogen. One genotype (Dh-86) showed moderate resistant reaction. The cultivars GPBD-4, Dh-102 and R-8808 showed susceptible reaction, others showed highly susceptible disease reaction. This could be due to soft cotyledons of the cultivar. Resistance to *A. flavus* may operate at the pod surface, within the testa/cotyledons. There appears to be different genes in conferring resistance to seed colonization, pre-harvest seed infection and aflatoxin production by aflatoxin producing fungi (Ghewande *et al.*, 1993; Thakur *et al.*, 2000).

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Efficacy of *Bacillus thuringiensis* var. *kurstaki* certain botanicals against major lepidopteran pests of sunflower, *Helianthus annuus* L.[1]

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Abstract

A field experiment with *Bacillus thuringiensis* var. *kurstaki* 0.2% (*B.t.k.*, Dipel 8L, HD-1 strain) and certain botanicals alone and in combinations, and endosulfan 0.07% as a standard check against major lepidopteran pests [*Spilosoma obliqua* (Walker), *Spodoptera litura* (Fab.) and *Helicoverpa armigera* (Hub.)] on sunflower (variety APSH-11) was carried out during *rabi*, 2003-04. The standard check, endosulfan 0.07% was highly efficacious in controlling the larval population of *A. obliqua, S. litura* and *H. armigera* by recording 66.3, 58.9 and 56.1% mean reduction of larvae with a seed yield of 1420 kg/ha. It was followed by the combination treatment, *B.t.k.*, 0.1% + neem seed kernel extract 2.5% with mean reduction in larval populations of 58.0, 55.5 and 53.2%, respectively and a seed yield of 1593 kg/ha. Further, endosulfan 0.07%, NSKE 5.0%, annona seed extract 5.0% (ASE, *Annona squamosa* L.), *B.t.k.*, 0.1% + NSKE 2.5% proved economical with cost benefit ratios of 1:3.9; 1:2.9; 1:2.5 and 1:2.2, respectively.

Key words: *B.t.k.*, botanicals, sunflower

Introduction

Sunflower (*Helianthus annuus* L.) is a promising oilseed crop next to groundnut, rapeseed-mustard and soybean in India. This crop suits to all kinds of soils and being photo and thermo insensitive, it can be grown throughout the year. Therefore, the crop is subjected to the damage of wide array of insect species. In India, more than 50 insect species have been found affecting the yields of sunflower, of which the major lepidopterans are *Helicoverpa armigera* Ihub.), *Spodoptera litura* (Fab.), *Spodoptera obliqua* (Walker), *Plusia orichalcea* (Fab.) and *Trichoplusia ni* Hubner (Goel and Kumar, 1990; Rogers, 1992).

To keep these insect pests under check, though synthetic agro-chemicals have been reported to be very effective, over dependence on them lead to problems like pest resurgence, pesticide resistance and residues and hazardous effect on beneficial insects like honey bees. In turn this effects the natural cross-pollination, thereby affecting the successful seed setting in sunflower. Hence, keeping the alternative forms of crop protection in view, the present field experiment on pests of sunflower using *Bacillus thuringiensis* var. *kurstaki* with certain botanicals was carried out to develop sustainable and environmentally safe pest control methods.

Materials and methods

A field trial on sunflower with the variety APSH-11 was laid out in a Randomised Block Design with three replications (plot size 3 x 5 cm^2) during *rabi*, 2003-04 in the farm of the Agricultural College, Bapatla. The treatments that were applied as foliar sprays include, *Bacillus thuringiensis* var. *kurstaki* 0.2% (*B.t.k.*, Dipel 8L, HD-1 strain), aqueous extracts of neem seed kernel extract 5% (NSKE, *Azadirachta indica* A. Juss.); sweet-flag rhizome extract 5% (SFRE, *Acorus calamus* L.); pungam seed extract 5% (PSE, *Pongamia glabra* Vent.) and annona seed extract 5% (ASE, *Annona squamosa* L.), combinations of *B.t.k.* and botanicals at half of their original concentrations, the insecticidal treatment endosulfan 0.07% as a standard check and an untreated check.

The two foliar sprayings were applied at 55 and 65 days after sowing (DAS) using hand compression sprayer during evening hours. The pre-treatment count of the lepidopteran larvae *viz.*, *S. obliqua*, *S. litura* and *H. armigera* was taken one day prior to each spraying, while the post-treatment counts were taken at second, sixth and tenth day after each spraying from randomly tagged plants leaving border rows. The data on larval population reduction was presented as mean efficacy of the two sprayings. The per cent larval population reduction in different treatments over untreated check was calculated by the modified Abbott's formula given by Flemming and Ratnakaran (1985). The data on the yield of sunflower seed from each treatmental plot after sun drying was recorded as kg/plot and kg/ha and was subjected to statistical analysis to test the significance of mean yield in different treatments.

Results and discussion

The data on the mean larval reduction after imposition of the two sprayings indicated that treatments either alone or

[1] Part of M.Sc. (Ag.) Thesis submitted by the senior author to ANGRAU, Hyderabad.

in combinations were significantly effective in bringing down the larval population over untreated check. Among all the insecticidal treatments tested, the standard check, endosulfan 0.07% was highly efficacious in controlling larval population of *S. obliqua, S. litura* and *H. Armigera*, by recording 66.3; 58.9 and 56.1% mean reduction of the larvae over untreated check, respectively. This is because of contact and stomach action of endosulfan, which is a broad-spectrum cyclodiene insecticide. However, the earlier reports indicating varied larval mortalities of *S. obliqua* on urd and sunflower (Pawar and Charati, 2000); *S. litura* on cabbage (Malathi *et al.*, 1999) and *H. armigera* on sunflower (Arya *et al.*, 1996) with endosulfan were due to variations in the concentrations used and the host crops tested.

Among the combination treatments, *B.t.k.*, 0.1% + NSKE 2.5% was superior in reducing the larval population of *S. obliqua, S. litura* and *H. armigera* by resulting in 58.0, 55.5 and 53.2% mean reduction in the respective larval populations over untreated check. It was followed by *B.t.k.* 0.1% + NSKE 2.5% (52.2, 50.1 and 47.1%, respectively), *B.t.k.*, 0.1% + ASE 2.5 % (46.8, 44.8 and 43.4%, respectively) and *B.t.k.*, 0.1% + PSE 2.5% (44.5, 43.4 and 41.1%, respectively). This clearly indicates the additive effect because of the combinations of *B.t.k.*, and the botanicals, NSKE, ASE and PSE.

B.t.k., is an aerobic, spore forming and gram positive bacteria with the insecticidal activity mainly due to δ-endotoxin that causes septicaemia and results in death of the insect, whereas, the insecticidal activity of NSKE is due to *Azadirachtin* that also results in other deleterious effects on growth and development of insects by interfering with the neuro-endocrine system. The bioactive principles of ASE is acetogenin, known for its contact, ovicidal, insecticidal and repellent action (Ohsawa *et al.*, 1990). The alkaloids, karanjin and pungoflavin are biologically active compounds in the PSE. They were reported to have ovipositional deterrency, antifeedant, larvicidal, insect growth regulatory, sterility, etc. (Kumar and Singh, 2002). Among the individual treatments, *B.t.k.* 0.2%, followed by NSKE 5.0% were highly efficacious in resulting 43.2, 39.1 and 37.2 and 41.2, 38.9 and 36.6% mean larval reductions of *S. obliqua, S. litura* and *H. armigera*, respectively over untreated check. Compared to the present efficacy of *B.t.k.* 0.2% with 43.2% reduction of *S. obliqua*. Pawar and Charati (2000) reported higher larval population reduction of about 70 to 80% on sunflower with *B.t.* formulations like Bactobite and Biobit. SFRE 5.0% was found moderately effective and recorded 36.7, 33.6 and 31.5% mean larval reduction of *S. obliqua, S. litura* and *H. armigera*, respectively which were lower compared to 57.4% larval reduction of *P. xylostella* on cabbage with 4.0% aqueous SFRE reported by Rajavel and Veeraraghavaihatham (1989).

ASE 5.0% was also found moderately effective and recorded 31.1, 28.3 and 26.8% mean larval reduction of *S. obliqua, S. litura* and *H. armigera*, respectively over untreated check. However, Raman *et al.* (2000) reported 74% larval reduction of *Aproaerema modicella* Dev. on groundnut using ethanol extract and oil concentrate of annona seed at 0.5% concentration indicating that aqueous extracts are less efficacious.

Among the solo insecticidal treatments, PSE 5.0% was the least effective but significantly superior over untreated check and recorded 28.6, 25.8 and 24.5% mean larval reduction, respectively. This is in agreement with the report of Kulat *et al.* (2001), who had recorded a moderate efficacy (16.3%) with 5.0% aqueous PSE against *H. armigera* on chickpea. The difference among the results could be attributed to different formulations, their concentrations, host-plant and the time interval of larval population count.

The seed yield of sunflower in different treatments was in the same trend as that of their efficacy (Table 1). The highly efficacious combination treatment of *B.t.k.* with the aqueous botanical extracts resulted higher seed yields of sunflower compared to those recorded in the individual treatments.

The highly efficacious *B.t.k.* 0.1% + NSKE 2.5% combination treatment recorded the highest seed yield (1593 kg/ha) with 44.8% increase in yield over untreated check. In the other combination treatments the ascending order of the yield and per cent increase in yield over untreated check were in combinations of *B.t.k.* with PSE, ASE and SFRE ranging between 1327 to 1520 kg/ha and 35.6 to 42.1%.

It is interesting to note that the seed yield in endosulfan 0.07% as standard check was 1420 kg/ha (38.0% increase yield over untreated check) is not the highest though endosulfan was the most efficacious treatment. This can be attributed to insecticidal effect of endosulfan against the honey bees, which play a major role in cross pollination for successful seed setting in sunflower. However, the present yield recorded was significantly higher compared to those of other treatments and also to that of 723 kg/ha reported by Bhosale *et al.* (1990) using endosulfan 0.05%.

Among the individual treatments, *B.t.k.* 0.2% recorded the highest yield of 1457 kg/ha (39.6% increase in yield over untreated check) followed by 5.0% of NSKE, SFRE, ASE and PSE with 1200 (26.7%), 1153 (23.7%), 1033 (14.8%) kg/ha, respectively. But, from the point of cost-benefit ratio (CBR), individual treatments like endosulfan 0.07% followed by NSKE 5.0% and ASE 5.0% proved economical with CBR ratios of 1:3.9, 1:2.8 and 1:2.5, respectively compared to 1:2.2 in *B.t.k.* 0.1% + NSKE 2.5%.

Table 1 Mean efficacy of *B.t.k.* and botanicals alone and in combination after the two sprayings against lepidopteran pests on sunflower during *rabi*, 2003-04

Treatment	Per cent reduction of larvae over untreated check			Mean seed yield (kg/plot)	Seed yield (kg/ha)	Cost benefit ratio
	S. obliqua	*S. litura*	*H. armigera*			
B.t.k. 0.2%	43.2 (41.0)^{f}	39.1 (38.4)^{f}	37.2 (37.2)^{f}	2.2^{b}	1457	1:1.2
NSKE 5.0%	41.2 (39.8)^{g}	38.9 (38.3)^{f}	36.6 (37.0)^{f}	1.8^{de}	1200	1:2.9
SFRE 5.0%	36.7 (37.1)^{h}	33.6 (35.1)^{g}	31.5 (33.8)^{g}	1.7^{da}	1153	1:1.2
PSE 5.0%	28.6 (31.7)^{i}	25.8 (29.9)^{i}	24.5 (29.0)^{i}	1.6^{f}	1033	1:1.6
ASE 5.0%	31.0 (33.6)^{i}	28.3 (31.7)^{h}	26.8 (30.7)^{h}	1.7^{ef}	1120	1:2.5
B.t.k. 0.1% + NSKE 2.5%	58.0 (50.0)^{b}	55.5 (48.3)^{b}	53.2 (46.9)^{b}	2.4^{a}	1593	1:2.2
B.t.k. 0.1% + SFRE 2.5%	52.2 (46.4)^{c}	50.0 (45.1)^{c}	47.1 (43.3)^{c}	2.3^{a}	1520	1:1.6
B.t.k. 0.1% + PSE 2.5%	44.6 (41.8)^{f}	43.4 (41.2)^{f}	41.1 (39.7)^{e}	2.0^{c}	1327	1:1.4
B.t.k. 0.1% + ASE 2.5%	46.8 (43.1)^{d}	44.8 (42.0)^{d}	43.4 (41.1)^{d}	2.1^{bc}	1367	1:1.5
Endosulfan 0.07%	66.3 (55.0)^{a}	58.9 (50.3)^{a}	56.1 (48.6)^{a}	2.1^{b}	1420	1:3.9
Untreated check	-	-	-	1.3^{g}	*880*	-
SEm±	0.2	0.2	0.3	0.1	-	-
CD (P=0.05)	0.4	0.5	0.5	0.1	-	-

B.t.k. : *Bacillus thuringiensis* var. *kurstaki*; NSKE : Neem seed kernel extract; SFRE : Sweet-flag rhizome extract; PSE : pungam seed extract; ASE : annona seed extract; Sig. : significant; NS : non-significant; DAS : days after sowing; DAT : Days after treatment

Note: Values in parenthesis are angular transformed values; Values in each column with similar alphabets do not vary significantly

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Effect of meteorological parameters on aphid, *Lipaphis erysimi* (Kalt.) population on Indian mustard, *Brassica juncea* (L.) Czern & Coss

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Abstract

Incidence and multiplication of mustard aphid, *Lipaphis erysimi* (Kalt) is mainly influenced by meteorological parameters. Field experiments were conducted at Punjab Agricultural University, Ludhiana during *rabi* season, 2003-04 and 2004-05 to evaluate the effect of meteorological parameters on mustard aphid. Mustard variety PBR 91 was sown on two different dates *viz.*, first week of November (D_1) and last week of November (D_2). The aphid population in second sowing (D_2) was very low during 2003-04 as compared to 2004-05. The aphid population showed a negative correlation with maximum, minimum and mean temperature in D_1 during 2003-04 and in D_1 and D_2 during 2004-05.

Key words: Mustard aphid, alate population, meteorological parameters

Introduction

Oilseed crops play an important role in India's agricultural economy. Insect pests reduce the crop production both quantitatively and qualitatively. More than 35 insect species attacks this crop at various growth stages, but mustard aphid, *Lipaphis erysimi* (Kalt) among these is the most harmful. This pest remains active throughout the growth period and feeds on foliage, inflorescence and pods of the crop. The losses may vary from 35.4 to 73.3% under different agro climatic conditions. On all India basis, the mean losses were reported as 54.2% (Bakhetia, 1983).

The incidence and multiplication of mustard aphid is largely influenced by various meteorological parameters. Information on abundance and distribution of aphid in relation to meteorological parameters is required for developing any insect pest management programme for specific agro-ecosystem. Keeping this in view, the present study was undertaken to correlate various meteorological parameters with mustard aphid population.

Material and methods

A field experiment was conducted at the Punjab Agricultural University, Ludhiana during two crop seasons of *rabi* 2003-04 and 2004-05, Indian mustard, *B. juncea* variety PBR 91 was sown on two different dates *viz.*, first week of November (D_1) and last week of November (D_2). The crop was raised as per recommendation package of practices of Punjab Agricultural University. Daily meteorological observations on temperature (°C), relative humidity (%), sunshine hours and rainfall were recorded from the Agro Meteorological Observatory (30° 54' N, latitude and 74° 48' E longitude and altitude of 247 m above the mean sea level) which was situated within 150 m of study area. Aphid population was observed from top 10 cm portion of the central shoot of ten randomly selected plants at weekly interval. The alate population was observed daily by using yellow sticky traps. Aphid population and alate population were correlated with different meteorological parameters. The step wise multiple regression analysis between aphid population and meteorological parameters was also conducted.

Results and discussion

Correlation between aphid population and meteorological parameters: Simple correlation coefficients were worked out between weekly aphid population and weekly meteorological parameters during 2003-04 crop revealed that the aphid population in D_1 showed a negative correlation with the maximum, minimum and mean temperature. However, in D_2 it showed a positive correlation with the maximum, minimum and mean temperature, however, the correlation was non-significant. During 2004-05, the aphid population showed a significant negative correlation with maximum, minimum and mean temperature in both D_1 and D_2. Kar and Chakravarty (2000) also reported a negative correlation between aphid population and temperature conditions. Ahuja (1990) also reported a negative correlation with aphid population and temperature (maximum and minimum). The aphid population showed a negative correlation with mean relative humidity (RH) during both the crop seasons and dates of sowing. Similarly, a negative correlation between aphid population and rainfall was observed for sowing dates during both the crop seasons. However, Singh *et al.* (1986) reported that the temperature (maximum and minimum), relative humidity (morning and evening) and sunlight had a positive effect on the population of mustard aphid.

The variation in aphid population during the two crop seasons for each date of sowing is shown in Fig. 1 and 2. The aphid population was high during 2004-05 as compared to 2003-04 in for each date of sowing. Furthermore, aphid population was high in late sown crop (D_2) as compared to early sown crop (D_1) during both the years. As relatively warm conditions of October and November were not so favourable for growth of aphid population in D_1 and the flowering stage of the early sown crop was almost over. Cool weather conditions of late December and January were experienced. Thus, the vulnerable vegetative phase of crop growth in D_1 escaped from aphid incidence. Similarly, Dhaliwal (2002) also reported that the late sown crop (25 November) was totally damaged by aphid and no pod formation was observed in late sown crop while the early sown crop (5 October) was totally free from aphid incidence and gave highest yield. These results are also in agreement with Upadhyay (1996), Singh *et al.* (1998) and Kar and Chakravarty (2000) who reported that delay in sowing caused a gradual increase in population of *Lipaphis erysimi* and ultimately resulted in reduction of yield. Similarly, Bhadauria and Jakhmola (1995) also reported that there was progressive increase in aphid population when the sowing was delayed from 4 November to 25 November.

Stepwise regression analysis: From the correlation study, it become clear that none of the meteorological parameter alone was responsible for multiplication and growth of the aphid. In nature no environmental factor exists in isolation in its action and one factor may act in combination with another. So, the stepwise regression analysis between aphid population and meteorological parameters in D_1 and D_2 during both the crop seasons was conducted to evaluate the cumulative effect of different meteorological parameters on aphid multiplication and development (Table 2 and 3). During 2003-04 and 2004-05 aphid population was positively correlated with minimum temperature and sunshine hours and negatively correlated with relative humidity and rainfall. The r-value for 2004-05 were highly significant as compared to 2003-04. The pooled data for both crop seasons (Table 4) revealed that aphid population was negatively correlated with mean temperature, sunshine hours and rainfall, however, it was positively correlated with mean relative humidity and showed highest r value (r=0.70).

Table 1 Correlation between aphid population and meteorological parameters for different sowing times during two crop seasons

Year		Correlation coefficients							
		TMX	TMN	TME	RHM	RHE	RHME	SSF	RF
2003-04	D_1	-0.13	-0.31	-0.20	0.07	-0.13	-0.82	0.26	-0.03
	D_2	0.25	0.06	0.20	-0.08	-0.42	-0.36	0.61	-0.41
2004-05	D_1	-0.41	-0.70	-0.66	0.30	-0.72	-0.21	0.41	-0.38
	D_2	-0.39	-0.62	-0.54	0.49	-0.28	0.02	0.46	-0.40

Where, TMX = Maximum temperature (°C); TMN = Minimum temperature (°C); TME = Mean temperature (°C)
RHM = Morning relative humidity (%); RHE = Evening relative humidity (%) RHME = Mean relative humidity (%)
SSH = Sunshine hours (hours/day); RF = Total weekly rainfall (mm)

Table 2 Multiple regression equations for aphid population and meteorological parameters under different two dates of sowing during *rabi*, 2003-04 crop season

	Regression equation	Multiple correlation coefficient ®
D_1	Y = 14.21 + 2.830 TMX - 6.26 TMN	0.48
	Y = 85.12-3.50 TME - 0.59 RHME + 4.33 SSH + 0.06 RF	0.60
	Y = 107.06 - 4.50 TMX + 1.61 TMIN - 0.71 RHME + 6.50 SSH	0.61
	Y = 107.04 - 4.49 TMX + 1.60 TMN - 0.71 RHME + 6.49 SSH + 0.01 RF	0.62
D_2	Y = -12.44 + 3.00 TMX - 4.42 TMN	0.46
	Y = 93.54 - 0.73 TME - 0.93 RHME	0.60
	Y = -9.52 + 3.05 SSH - 0.25 RF	0.62
	Y = 1.15 - 1.65 TME + 0.06 RHME + 4.75 SSH - 0.42 RF	0.70

Table 3 Multiple regression equations for aphid population and meteorological parameters under two dates of sowing during *rabi*, 2004-05 crop season

	Regression equation	Multiple correlation coefficient ®
D_1	Y = 145.22 - 1.19 TMX - 11.15 TMN	0.70
	Y = 307.84 - 9.15 TME - 2.35 RHME	0.81
	Y = 307.84 - 9.14 TME - 2.35 RHE	0.81
	Y = 287.40 - 8.81 TME + 0.18 RHM - 2.37 RHE	0.81
	Y = 383.46 - 11.11 TME - 2.81 RHME - 4.17 SSH	0.83
	Y = 368.69 - 12.84 TME - 2.18 RHME - 4.10 SSH - 0.35 RF	0.83
D_2	Y = 136.80 + 0.43 TMX - 9.65 TMN	0.61
	Y = 111.52 - 8.98 TME + 0.95 RHME	0.59
	Y = -445.74 - 3.33 TMX - 2.31 TMN + 6.21 RHM	0.67
	Y = -197.03 - 7.01 TME + 3.82 RHME + 8.22 SSH	0.67
	Y = -180.24 - 10.53 TME + 5.09 RHME + 1.50 SSH - 1.87 RF	0.85

Table 4 Multiple regression equations for aphid population and meteorological parameters (pooled data 2003-04 and 2004-05)

Regression equation	Multiple correlation coefficient ®
Y = -61.79 - 2.65 TMX - 2.31 TMN + 2.99 RHM - 1.62 RHE	0.59
Y = 115.35 - 12.60 TME + 1.85 RHME - 1.49 SSH - 1.56 RF	0.71
Y = 116.79 - 10.26 TME + 1.11 RHME - 0.94 SSH	0.56
Y = 78.20 + 2.80 TMX - 10.16 TMN	0.55

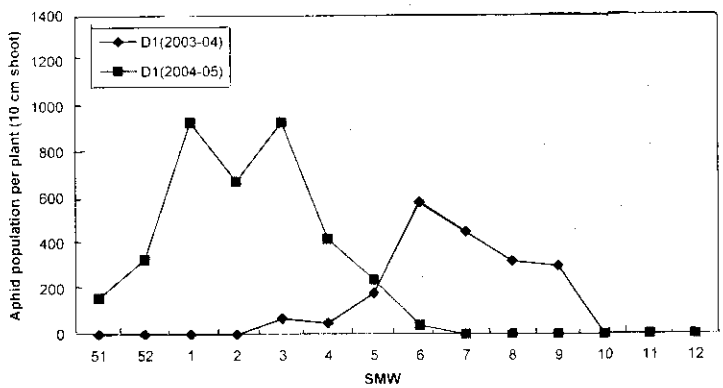

Fig.1 Mean aphid population in D1 during crop seasons of 2003-04 and 2004-05

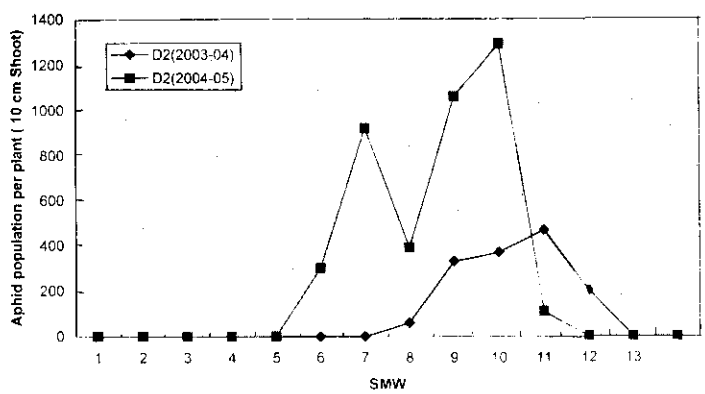

Fig.2 Mean aphid population in D2 during crop seasons of 2003-04 and 2004-05

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A study on population fluctuation of the safflower fly, *Acanthiophilus helianthi* Rossi (Diptera : Tephritidae) and field evaluation of losses in the Ghom province

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Abstract

Safflower fly, *Acanthiophilus helianthi* Rossi is one of the important pests of the safflower in Iran. The aims of this study were to determine the seasonal abundance and extent of losses caused by safflower fly, *A. helianthi* Rossi, to safflower crop under field condition of Ghom region, during 2002 and 2003. Safflower fly adults were monitored with yellow sticky traps. Eggs, larvae, pupae and amount of infestation by *A. helianthi* were monitored weekly by observing 30 capsules in each field. Samples were collected from the field in paper bags and transported to the laboratory. Parasitoids that emerged were identified and their density recorded. The adults of *A. helianthi* commenced appearing on safflower crop in Ghom between the 1st week of April upto 4th week of June and infestation level of *A. helianthi* larvae and pupae to capsule was from 1st of April to end of June. Therefore, it declined due to maturity of the crop. Its maximum population in the 1st generation was seen in the 1st week of May and 2nd generation in the 1st week of June. This fly had 2 generations in Ghom during autumnal safflower and 3rd generations on the spring crop and weeds. The accomplished studies related to assess the fly, showed that 10-33% of capsule were damaged because of feeding by the larvae of this fly. Parasitic wasps, *Antistrophoplex conthurnatus* Masi (Torymidae) was observed as parasitoids of larvae and pupae, however, the parasitism rate was very low.

Key words: *Acanthiophilus helianthi*, safflower, parasitoid

Introduction

Safflower (*Carthamus tinctorius* L.) an important oilseed crop, is recently introduced in Iran for increasing oil production. The crop occupied about 10000 ha during 2003 with a total production of about 8000 tonnes (Anonymous, 2005). The safflower plants have been found damaged by over 80 species of insects, mites and nematodes throughout the world (Singh *et al.*, 1999). In Iran the capsule/fruit fly, *Acanthiophilus helianthi* Rossi is the most destructive pest. The newly hatched larvae of this fly fed on the soft parts of the heads, while those in the second and third instar did so on the soft seeds within. The larval stage lasts for about 10 days in 1st generation and pupal period is 7-10 days. Winter is passed as pupae in heads, left in the fields after harvesting or weeds (Mirzaei, 1970; Al-Ali *et al.*, 1977; Hegazi and Moursi, 1983). The present studies deal with the population fluctuation of the safflower fly, its biology and field evaluation of losses in Ghom province of Iran.

Materials and methods

Field studies were carried out in two safflower fields of 4000 m^2 located in Ghanavat and Asgarieh villages of Ghom city. Ten yellow sticky traps were used to monitor the onset of adult flies activity by hanging vertically on 30 plants at equal distances from the edges of the fields. The traps were checked weekly and the number of each sex of the trapped fly determined. At the same time, 30 safflower plants were randomly collected at weekly intervals from both the fields for recording the young stages of the pest. One flower from each plant was used to count the number of different biological stages of the fly under a Stereomicroscope. For seeking natural enemies, in addition to 30 collected flowers, 100 more flowers were collected at weekly intervals and the present stages of the fly were reared for probable parasitoids of the pest.

Results and discussion

Number of generation: Based on the Fig. 1 and 2, the pest had three peaks i.e., during 1st week of May, last week of May and last week of June and it had two generations (Fig. 3 and 4). Sticky traps documented that the appearance of the flies started from 3rd week of the April and data collected from flower samples showed that egg laying initiated 5 days later. During the first generation, eggs were deposited under or inside the brackets while in the 2nd generation, the eggs were mostly laid on the florets. In the winter when safflower seeds were mature, a visible migration (Fig. 3 and 4) occurred onto the spring safflower and weeds of the neighbouring fields; so early planting of the winter safflower could help in avoiding

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more damage to the crop. This finding is in conformity with Singh *et al.* (1982) who suggested that early planting would considerably decrease the injury amount as compared to late planting.

Seasonal abundance and adults monitoring: The results of sticky traps are presented in Fig. 1 and 2, based on these data the on set of the adults in the selected fields lasted from 3rd week of the April to last week of June or 1st week of July. In 2002, peak of the adult population of the two generations occurred during 3rd week of May whereas in 2003 these points were observed 1 or 2 weeks later. Number of male adults was more than the female in early season, so it could be concluded that male flies emerged earlier.

Capsule data: According to the data summarised in Table 1 and Table 2, it could be concluded that female adults started laying eggs 5 days after emergence. The first generation was of about 6-12 days whereas it became shorter in next generation. First larvae appeared in the end of April, which denoted that egg incubation could be of about 4-6 days. In Asgarieh village amount of larval infestation was 0-1.07 larvae per boll during the 2 years of the study but it was lower in Ghanavat village documenting upto 0.93 larvae/boll. First instar larvae fed on the leaflets for a short period and then entered into the bolls when they were completely closed and measured about 1 cm in diameter. Larval period, based on the Fig. 3 and Fig. 4 was about 11-12 days; number of larva/boll ranged from 1-13, which is similar to the findings of Selim (1978) who reported 1-11 larva in each boll in safflower fields in Iraq. The natural enemies discovered from the collected larvae and pupae was *Antistrophoplex conthumatus* Masi (Torymidae) and the parasitism rate was very low. Other species of fly, *Chaetorellia loricata* Rondani that going out from bolls an d damage, it was in low numbers and reached maximum to 2%.

Infestation rate: In the Ghom region infestation by safflower fly coincided with boll formation in the end of April. Rate of infestation by different stages of the pest is presented in Table 1 and Table 2. The larval feeding inhibits flower growth during the first generation but in the next generation this injurious activity led to no boll formation and reduction of the seed formation. Based on the information collected in Fig. 3 and 4, it could be construed that total damage of the pest during the two years under study was about 10-33%.

Sex ratio: The analysis of the data collected by the yellow sticky traps (Fig. 1 and 2), revealed that the number of the two sexes of the pest was approximately equal during the entire study and ranged from 1-1.02 and 1-1.07 in 2002 and 2003, respectively.

Acknowledgement: The authors are extremely grateful to Plant Pests and Diseases Research Institute for providing facilities for these studies.

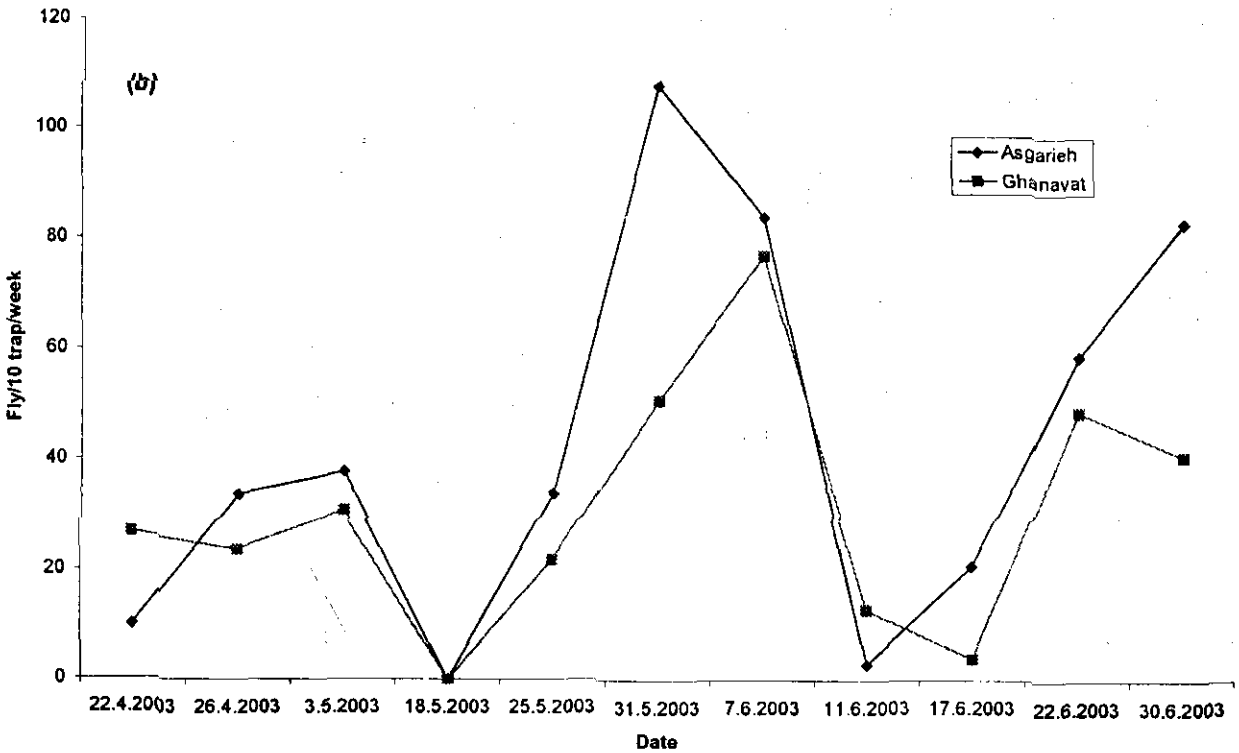

Fig. 1. Population abundance of adults of *Acanthiophilus helianthi* during 2002

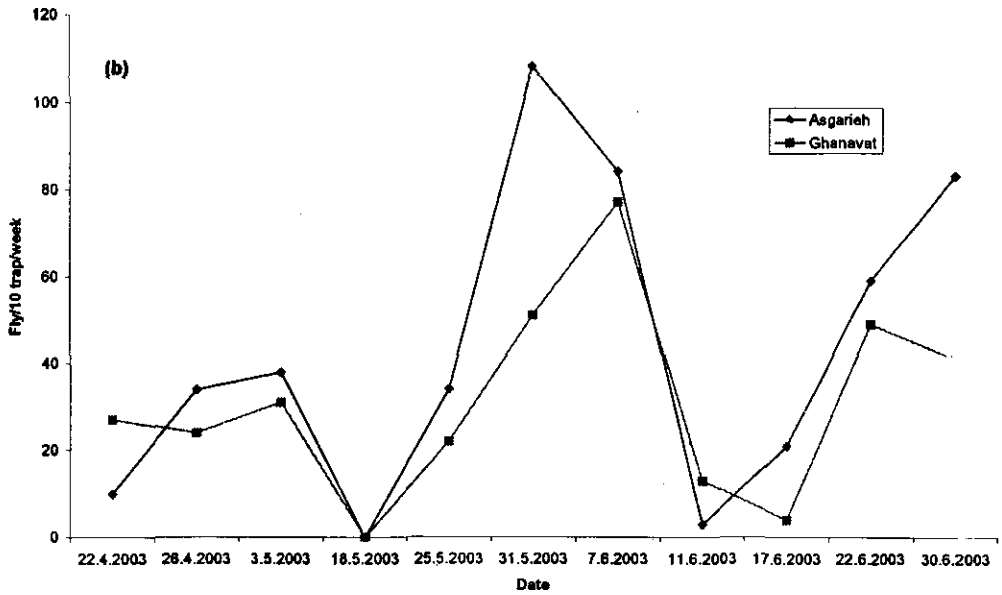

Fig. 2. Population abundance of adults of *Acanthiophilus helianthi* during 2003

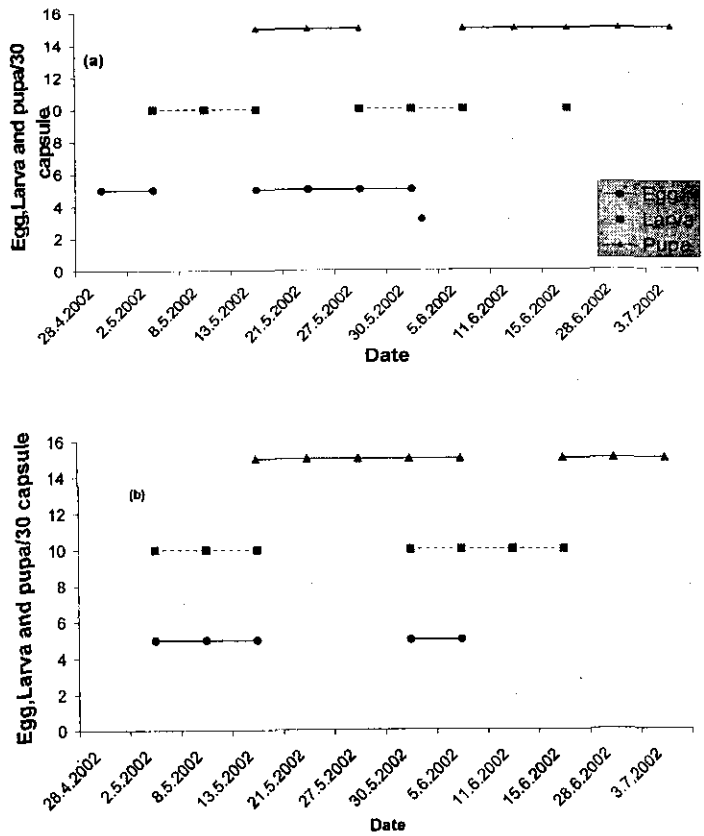

Fig. 3. Growth phase of *A. helianthi* on safflower at Asgarieh (a) and Ghanavat (b) during 2002

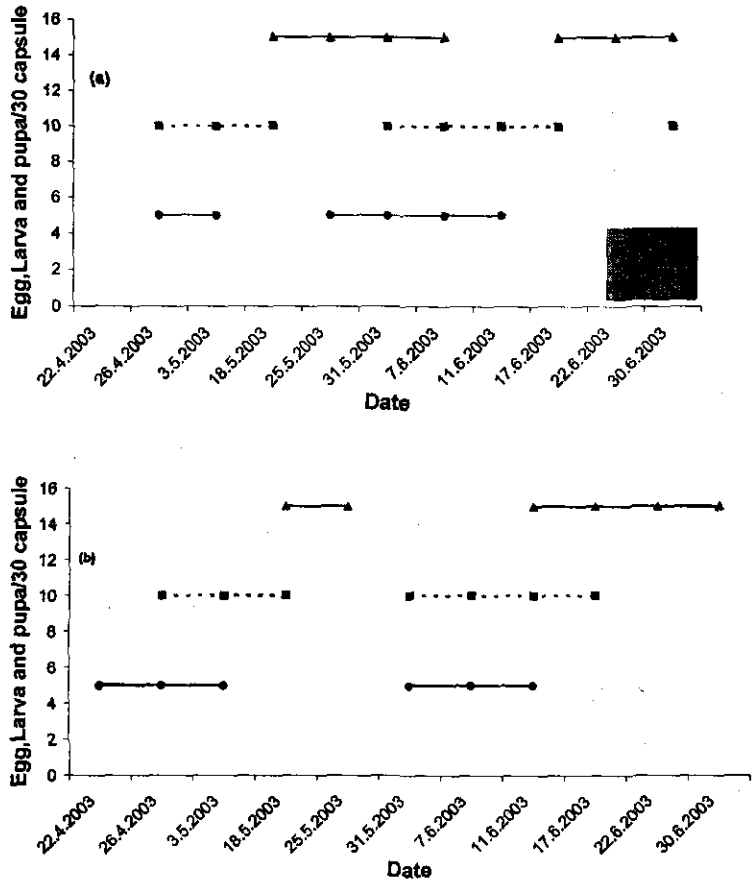

Fig. 4. Growth phase of *A. helianthi* on safflower at Asgarieh (a) and Ghanavat (b) during 2003

Table 1 Mean number of eggs, larvae and pupae population and infestation of capsule (%) by *A. helianthi* between April to June during 2002 at Asgarieh and Ghanavat based on field scouting (30 capsule)

Date	Asgarieh				Ghanavat			
	Egg	Larva	Pupa	Capsule infestation (%)	Egg	Larva	Pupa	Capsule infestation (%)
28.04.2002	0.40	0.00	0.00	0.0	0.00	0.00	0.00	0.0
02.05.2002	0.60	0.16	0.00	0.0	0.10	0.23	0.00	0.0
08.05.2002	0.00	0.70	0.00	0.0	1.63	0.90	0.00	0.0
13.05.2002	0.00	0.46	0.30	17.0	0.60	0.47	0.17	10.0
21.05.2002	1.53	0.00	0.70	23.0	0.00	0.00	0.63	17.0
27.05.2002	1.17	0.37	0.47	17.0	0.00	0.00	0.37	13.0
30.05.2002	0.70	0.87	0.00	17.0	2.20	0.17	0.70	33.0
05.06.2002	0.43	0.23	0.50	23.0	0.43	0.63	0.40	20.0
11.06.2002	0.00	0.00	0.60	23.0	0.00	0.47	0.00	27.0
15.06.2002	0.00	0.33	0.53	33.0	0.00	0.37	0.30	27.0
28.06.2002	0.00	0.00	0.33	23.0	0.00	0.00	0.83	23.0
03.07.2002	0.00	0.00	0.57	13.0	0.00	0.00	0.43	17.0

Table 2 Mean number of eggs, larvae and pupae population and infestation of capsule (%) by *A. helianthi* between April to June during 2003 at Asgarieh and Ghanavat based on field scouting (30 capsule)

Date	Asgarieh				Ghanavat			
	Egg	Larva	Pupa	Capsule infestation (%)	Egg	Larva	Pupa	Capsule infestation (%)
22.04.2003	0.00	0.00	0.00	0.0	0.63	0.00	0.00	0.0
26.04.2003	0.87	0.20	0.00	0.0	1.43	0.37	0.00	0.0
03.05.2003	1.30	0.80	0.00	0.0	0.77	0.57	0.00	17.0
18.05.2003	0.00	0.63	0.37	23.0	0.00	0.87	0.30	33.0
25.05.2003	0.43	0.00	0.53	10.0	0.00	0.00	0.70	17.0
31.05.2003	1.90	0.30	0.23	30.0	0.90	0.40	0.00	10.0
07.06.2003	0.30	1.07	0.70	33.0	0.30	0.93	0.00	17.0
11.06.2003	0.37	0.47	0.00	13.0	1.10	0.63	0.53	27.0
17.06.2003	0.00	0.27	0.23	10.0	0.00	0.17	0.37	23.0
22.06.2003	0.00	0.00	0.53	17.0	0.00	0.00	0.87	30.0
30.06.2003	0.00	0.17	0.40	13.0	0.00	0.00	0.23	13.0

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Multimedia information system for sunflower, *Helianthus annuus* L.

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Abstract

In the era of liberalization, the importance of accurate and timely information is increasing. Access to information and improved communication with minimized loss in transmission is a crucial requirement for sustainable agricultural development. Providing need based technology and information at right time to right people is one of the key components to achieve the goal of empowerment of the peasant communities. Towards this direction, a multimedia based sunflower information system has been developed which caters to the needs of various end users like extension workers, academicians, researchers, farmers and others involved and interested in accessing the information about the sunflower crop. The information about various aspects of sunflower crop like botany, improved cultivars, climatic conditions, nutrient management practices and insect pests are collected, compiled and a user-friendly graphical user interface (GUI) was developed.

Key words: Graphical user interface (GUI), information technology, multimedia, random access, sunflower

Introduction

Sunflower (*Helianthus annuus* L.,) is an important oilseed crop cultivated for its premier oil and manifold uses both of industrial and pharmaceutical importance (Anonymous, 2002, 2002a, 2002b,2002c,2003,2003a).

Though vast information is available, aggregating the information and designing the system in such a way that appropriate information is available to the user by choice with a simple operation is inadequate. The information transfer between researchers and farmers must be need based, timely and complete to fulfill the farmers need (Vinod Kumar *et al.*, 2004). The effect of research in agriculture production process depends on the how effectively the resulting scientific information can be transformed into increased knowledge held by farmers. Scientific solution to this problem is to use information technology which can provide innovative services in almost every human activity provided, one has the capability to use them properly according to their need, (Chai *et al.*, 1994; Allan *et al.*, 2000). With the help of Information Technology, information can be disseminated in more useful manner and as users need. The farmers need information for better farming and they depend on the various available sources of information. Proper use of Information Technology is a scientific solution for effective compilation and interpretation of available information into electronic format (Kuhlmann and Brodersen, 2001). A graphical user interface (GUI) was developed to provide a variety of capabilities to the end user (Beck *et al.*, 1994). As a result multimedia information system on sunflower was developed which provides to various users, the information as and when required.

Materials and methods

The information on sunflower i.e. introduction of the crop, taxonomy, area and production, botany, improved varieties/hybrids, climatic and soil conditions under which the crop is cultivated, agronomic practices and pest management strategies were collected through literature search and compiled in such a way that the information needs of various users is satisfied (Anonymous, 2002, 2002a, 2002b, 2000c, 2003, 2003a). The feasibility of information technology was conducted during the year 2002 to identify the needs of the various end users. The information gathered is further classified into various modules and sub modules (Fig.1). Each sub module has complete information with a set of photographs related to a particular aspect of the crop. Macromedia Authorware 6.5 was used to develop the information system. Authorware provides the users random access facility by means of which the user can navigate from one screen to another as per choice. By this interactiveness the user can take the advantage of accessing any information on sunflower crop at any point of time.

System Requirements: The system can run on Pentium II and above machines with a CD/DVD drive with at least 64 MB RAM running windows 98 and above.

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Results and Discussion

Sunflower information system is broadly divided into seven major modules - Introduction, Botany, Improved cultivars, Crop Production, Insect pests, Diseases and Diagnosers which include sub modules within the main module to cover almost all the aspects of the crop. The diagnosers module has various identifier screens with a set of images which can identify the corresponding symptom and by a single click the user is provided with the information of his interest.

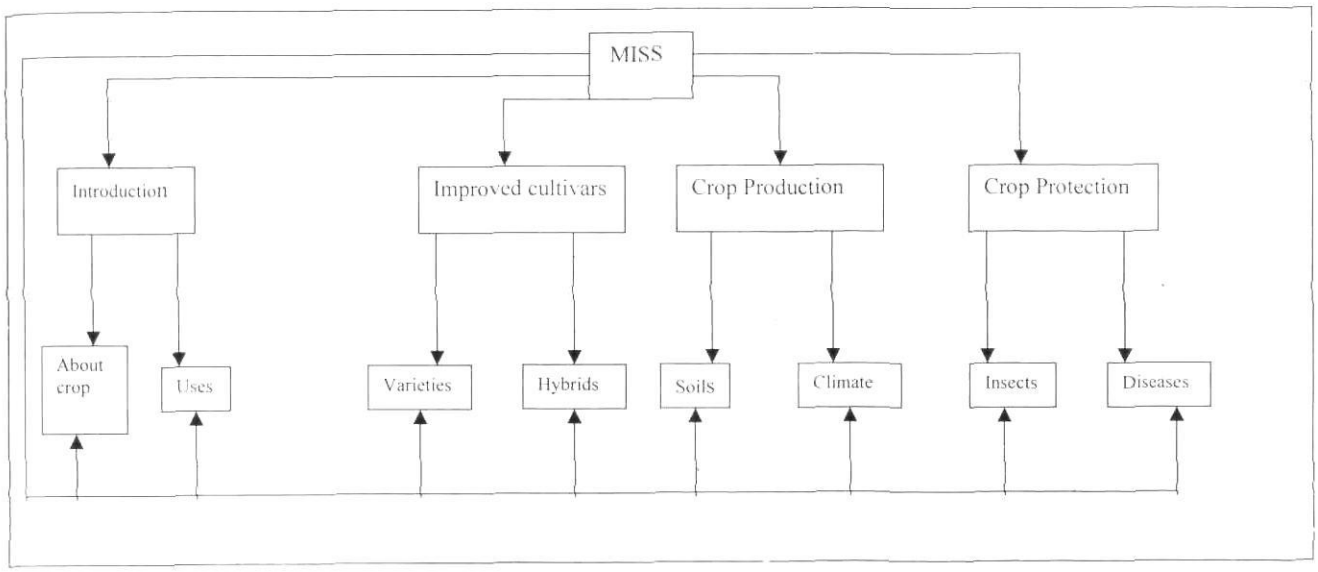
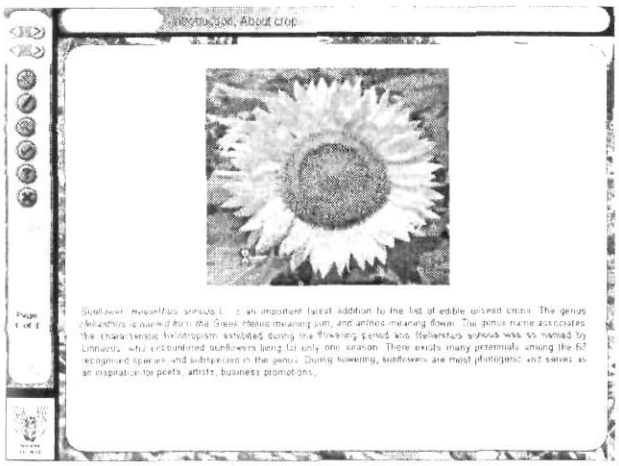


Fig. 1. Access of information in sequential and random manner

Introduction: The introduction module gives the *information about the species of the crop, where it is* grown, its production and productivity details, distribution pattern, etc.



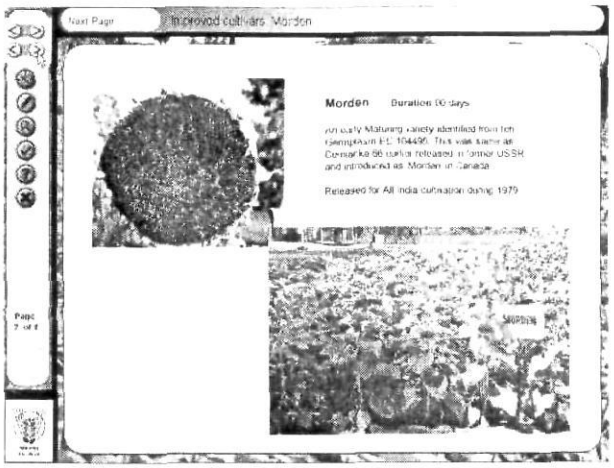
Botany : This module discusses about the various growth stages, leaves, roots, morphology, inflorescence details, stem, etc.

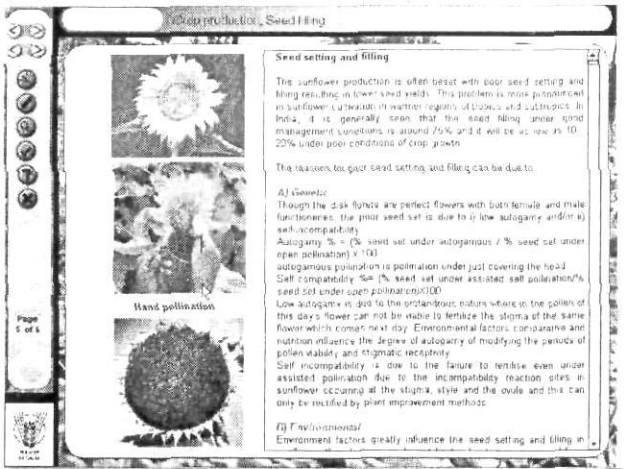
Improved Cultivars: The improved cultivars module has two sub modules in which the varieties and hybrids are discussed. The details like where the particular cultivars are used, duration of the crop, average yield, oil percentage and their salient features are discussed.

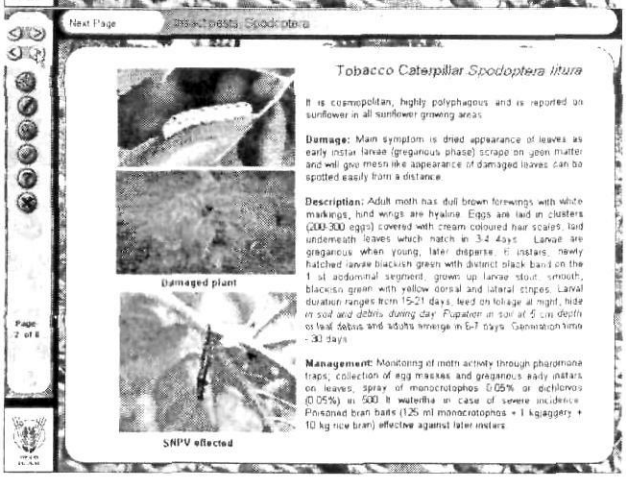
Crop Production: This module deals with crop management. It covers the details like under which climatic conditions the crop is raised, suitable soils, cropping patterns, nutrient management, weed management, irrigation management practices , etc. The details like how the nutrient deficiency symptoms are identified, and when harvesting has to be done are also discussed in detail in this module.

Insect Pests: The yield of the crop depends on how *effectively it is protected against the insect pests.* So care

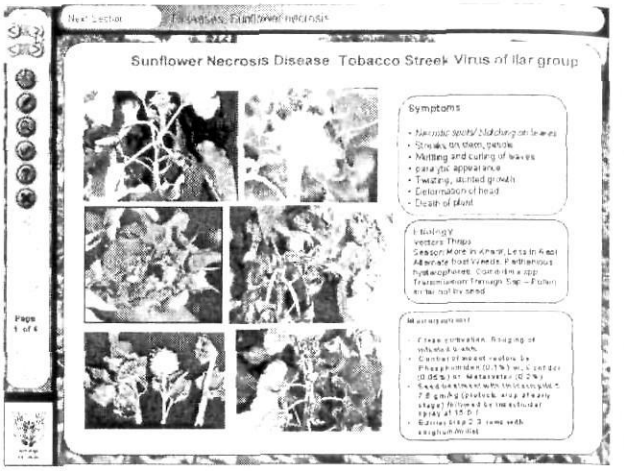
was taken to include the details regarding the major insect pests affecting the sunflower crop.

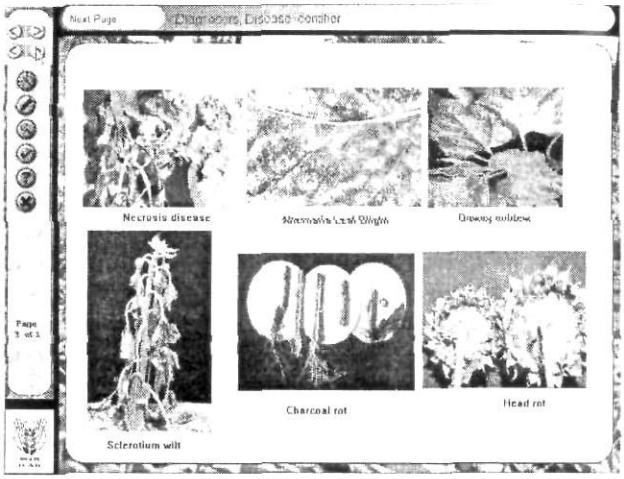






Diseases : Another factor, which influences the yield of a crop, is the diseases, which affect the crop at different stages. In this chapter the symptoms of almost all the major diseases affecting the crop along with their management practices are discussed in detail.





Diagnosers: Multimedia sunflower information system is provided with diagnoser modules which play a major role for the package. This module has various identifier

screens with respect to insect pests, diseases, and nutrient deficiencies with a set of images in each screen. The user by identifying the image, can get the entire information with respect to that particular symptom by just a single click on the image.

Sunflower information systems was designed in such a way that the user can access any information at any point of time. The system has a random search as well as random access facility. The system can be used for interactive self-learning as the users can proceed at their own pace. The system also has a sequence of slides in our national language also. If the user is interested to view the information in national language he can directly reach the point and from there can navigate to any other point.

The package on Multimedia information systems on sunflower has a wide range of images, which covers the various crop stages, insect pests, diseases, deficiency symptoms etc. With the help of these images the user can navigate directly to the exact point about which he is interested. As the entire information is just a few clicks away from the user, he can access the information as and when required instead of going through large volumes of books and journals for information.

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Growth trends in major oilseeds - A statewise analysis

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Abstract

The oilseeds scenario in the country has undergone a dramatic change in recent years due to various incentives and institutional support given by the Government for the development of this sector. The present study made an effort to inquire about the trends in area, production and yield of oilseeds in the major oilseeds producing states of India. The analysis showed that there is high degree of fluctuation in the annual oilseeds area, production and yield. The study also showed that the significant positive growth in *area, production and yield of oilseeds during overall* period. However, the productively growth in the total oilseeds had declined in Post-TMO period as compared to the Pre-TMO period. Therefore, the careful attention must be given to sustain and augment the productivity of oilseeds in different states to meet the future demand.

Key words: Groundnut, growth rates, coefficient of variation

Introduction

The oilseeds scenario in the country has undergone a dramatic change in recent years due to various incentives and institutional support given by the Government for the development of this sector. The Government of India constituted the Technology Mission on Oilseeds (TMO) in 1986. The total oilseeds production has more than doubled from 10.83 m. tones in 1985-86 to 25.29 m. tones in 2003-04. A series of farmer oriented programmes launched by the TMO along with better availability of crop production technologies, inputs, services and support price policy were together responsible for the achievements. However, there is a high degree of fluctuation in the annual production of different oilseeds (Goswami *et al.*, 1995).Therefore, the present study was carried out to know the trends in area, production and yield of oilseeds in the major oilseeds producing states of India.

Materials and methods

For the present analysis groundnut, sesame, rapeseed and mustard, sunflower soya bean and total oilseeds have been considered. The compound growth rate and coefficient of variation techniques have been used for the present analysis (Goswami *et al.*, 1995). The required time- series data on oilseeds area, production and yield for the period 1971-1972 to 2002-2003 were obtained from the various issues of Agricultural Statistics at a Glance published by Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India. The present study covered 33 years from 1971-1972 to 2002-2003. The analysis considered three periods *viz.*, Pre - TMO period (1971-72 to 1985-86), Post-TMO period (1986-87 to 2002-2003) and the Overall Period (1971-72 to 2002-03).

Results and Discussion

The Compound growth rates and co-efficient of variation in area, production and yield of groundnut, sesame, rapeseed and mustard, sunflower, soya bean and total oilseeds were analysed and discussed below in different heads.

Groundnut: Among the selected states, the significant negative growth (-4.32 %) was noticed during the I period in Madhya Pradesh. In the over all period, the significant negative growth in area were noticed in Madhya Pradesh (-2.48 %), Maharastra (-1.72 %) and Uttar Pradesh (-4.44%). The negative area growth was noticed in the total area at the country level and it was not significant. The production growth rate for groundnut was positive in Andhra Pradesh, Gujarat, and Karnataka in the I period. During the II period, Gujarat and Tamil Nadu showed positive growth in groundnut production. In the overall period, all selected states showed positive production growth expect Madhya Pradesh and Uttar Pradesh. At the country level, area, production and yield growth were higher in II period as compared to the I period.

The variability in the area was highest in Karnataka (157.82 %) followed by Uttar Pradesh (47.89 %) and Madhya Pradesh (26.94 %) the overall period. The production variability was highest in Gujarat (49.65 %) followed by Uttar Pradesh (48.16 %) and Andhra Pradesh (35.32 %) and the yield variation was highest in Gujarat (48.85 %) in the overall period (Table 1).

Sesame: The Area and productivity growths were positive in Gujarat, Orissa and Tamil Nadu during the period I. The area growth was positive and significant (6.89 %) in Gujarat and it showed significant negative growth in Orissa (-13.59 %) and Tamil Nadu (-3.70 %) during II period. The production and yield growth were significant and negative

in Orissa during the same period. The yield showed significant negative growth in Orissa (-6.89 %) and positive growth in Tamil Nadu (4.82 %) in the period. During the over all period, the area under sesame showed significant positive growth in Gujarat (4.95%) and significant negative growth in Madhya Pradesh (-4.95%) and Uttar Pradesh (-6.01%). India as whole, there is significant positive growth in area (1.24%) and productivity (2.33%) during overall period (Table 2). The area under sesame showed highest variation in Orissa (82.23 %) during II period and lowest variation in Andhra Pradesh (13.67 %). The highest (82.78 %) and lowest variation (14.68 %) was recorded in Orissa for production during overall period and II period. The highest productivity variation was recorded (60.27 %) in Rajasthan during II period and lower variation (16.08 %) was noticed in Tamil Nadu during I period. India as a whole there was not much variation among the area, production and productivity.

Rapeseed and Mustard: Among the selected major rapeseed and mustard growing states, the production showed positive growth during overall period except in Punjab (-0.32%) and Uttar Pradesh (-0.25%) and the states like Haryana (9.53%), Madhya Pradesh (7.11%), Rajasthan (11.35%) and West Bengal (9.23%) registered significant positive growth. The area and productivity showed a significant positive growth in major states except in Punjab (-2.68%) and Uttar Pradesh (-2.98%).

The area under rapeseed and mustard showed highest variation in Rajasthan (79.05 %) during overall period, while lowest variation was noticed in Assam (6.72 %) during II period. The production of rapeseed and mustard recorded highest variation in Rajasthan (79.26%) during overall period and lowest variation was recorded in Uttar Pradesh (19.56 %) during the same period. The variation in productivity of rapeseed and mustard was recorded highest in Haryana (38.08 %) during overall period and lowest variation in Assam (7.32%) during II period. For overall period, India recorded 30.08 %, 46.63 %and 26.03% variation in area, production and productivity respectively (Table 3).

Sunflower: The production of sunflower in all the major growing states recorded positive growth in overall period except in Tamil Nadu. Among the selected sunflower growing states, Andhra Pradesh (17.81%), Karnataka (13.13%) and Maharastra (12.26%) recorded significant positive growth which was due to increase in the growth of area and productivity. The area under sunflower recorded significant positive growth in Andhra Pradesh (15.34%), Karnataka (14.39%) and Maharastra (10.46%). The production recorded negative and significant growth in Tamil Nadu (-15.7%) and productivity recorded significant positive growth (6.27%) during II period, For India as whole, area and production recorded significant positive growth of 11.14 and 9.66% during overall period.

The area under Sunflower exhibited the highest variation in Andhra Pradesh (100.39 %) during overall period and lowest variation was also observed in the same state (20.89 %) during II period. The production of sunflower recorded highest variation in Uttar Pradesh (104.55 %) during overall period and the lowest in Karnataka (30.54 %) during II period. The productivity of sunflower recorded highest variation in Karnataka (49.89 %) during I Period and the lowest in Karnataka (13.78%) during II period. India as a whole, the area recorded highest variation (77.41%) during overall period and the lowest variation of 27.26% was observed during II period. The production recorded highest variation of 119.46% during overall period and lowest variation of 34.93% during period II.

Safflower: Among the selected major safflower growing states, the production of safflower recorded significant positive growth in Karnataka (15.14%) and Maharashtra (9.98%) during period I. During period II, the area of safflower recorded significant negative growth in Karnataka (-6.48%) and Maharashtra (-5.41%). The productivity recorded positive significant growth in Andhra Pradesh (2.09%) and Karnataka and (4.87%) during the over all period. India as a whole, the area, production and productivity recorded significant positive growth during period I (Table 5).

The area under safflower exhibited highest variation in Andhra Pradesh (44.62 %) during overall period and lowest variation in Maharastra (19.00 %) during period I. The production and productivity of safflower recorded highest variation in Karnataka during I period. The production recorded lowest variation in Andhra Pradesh (30.51 %) during I period and productivity recorded lowest variation in Andhra Pradesh (18.81 %) during the II period. India as a whole, the production and productivity recorded highest variation of 45.81 and 31.36 % respectively, during I period and production and productivity recorded lowest variation of 37.73 and 21.29 % respectively, during II period. The area under safflower recorded highest variation (31.11 %) during II period and lowest variation (17.40 %) during I period (Table 5).

Soybean: Among the selected soya bean growing states, the production of soya bean showed significant positive growth in Madhya Pradesh (20.69%), Maharastra (31.00%) and Rajasthan (26.43%) in overall period. During period I and period II, area and production in Maharastra and Madhya Pradesh recorded significant positive growth. India as a whole, the area and production showed significant positive growth while productivity showed no significant growth in period II and overall period (Table 6).

The Table 6 showed that the variation in production of soya bean was highest in Madhya Pradesh (102.24 %) during period I and lowest variation production was also noticed in the same state during period II. The area under soya bean showed highest variation in Madhya Pradesh (104.97 %) during period I and lowest variation in the

same state during period II. The productivity recorded highest variation in Rajasthan (28.58 % and lowest variation in Madhya Pradesh (19.41%t) during overall period. The highest variation in production (104.40 %) and productivity (20.65 %) was recorded during overall period for India as whole while highest variation in area (98.32 %) was recorded during the period I. The lowest variation was recorded in area (42.89 %), production (50.89 %) and productivity (18.79 %) during period II.

Total oilseeds: Among the selected major oilseeds growing states, the production of total oilseeds showed significant positive growth in Karnataka (3.07%), Madhya Pradesh (8.57%) and Maharastra (4.74%) during overall period and all other states showed positive growth and non significant during the same period except Uttar Pradesh. Similarly, country as a whole showed a significant positive growth in area (1.65%), production (3.66%) and productivity (1.98%) during overall period (Table 7). The results of our studies are in line with the findings of Goswami *et al.* (1995), Gupta *et al.* (1999), Ramasamy and Selvaraj (2002) and Vashishtha (2003).

Area under total oilseeds showed highest variation in Madhya Pradesh (44.83 %) during overall period and lowest variation in Maharastra (7.75 %) during I period. The production variation was highest in Madhya Pradesh (75.39 %) during overall period and lowest variation in Tamil Nadu (16.93 %) during I period. The productivity recorded highest in Uttar Pradesh (47.80 %) during overall period and lowest variation was recorded in Tamil Nadu (11.64 %) during I period. India as a whole, the production recorded highest variation of 36.73 % and lowest variation of 4.33 % during overall period.

Table 1 Compound growth rates and coefficient of variation of area, production and yield of groundnut in major states of India

State	Period-I (1971-72 to 1985-86)			Period-II (1986-87 to2002-03)			Over all period (1971-72 to2002-03)		
	A	P	Y	A	P	Y	A	P	Y
Andhra Pradesh	1.27 (0.70)	1.49 (0.42)	-4.96 (0.68)	-1.21 (0.75)	-2.72 (0.78)	-1.45 (0.61)	1.67 (2.02)	1.74 (1.17)	0.19 (0.10)
CV (%)	13.31	22.67	29.92	15.57	29.03	20.44	23.74	35.32	25.15
Gujarat	1.82 (1.42)	21.30 (0.27)	0.48 (0.06)	1.09 (0.64)	3.66 (0.39)	2.54 (0.31)	0.19 (0.32)	0.70 (0.22)	0.50 (0.18)
CV (%)	11.65	40.52	38.80	12.41	56.58	55.77	11.91	49.65	48.85
Karnataka	-0.70 (0.38)	1.62 (0.50)	-2.46 (0.72)	-2.98 (0.44)	-1.44 (0.53)	-0.12 (0.07)	1.44 (0.66)	1.92 (1.61)	0.89 (0.10)
CV (%)	12.27	21.86	32.10	160.18	22.07	14.23	157.82	30.31	23.67
Madhya Pradesh	-4.32* (-2.81)	-4.31 (1.60)	-0.009 (0.004)	-1.93 (1.19)	-1.60 (0.63)	1.75 (0.92)	-2.48** (3.98)	-0.55 (0.50)	2.33 (2.80)
CV (%)	22.14	29.25	16.15	15.24	22.41	14.58	26.94	24.92	25.74
Maharastra	-0.27 (0.21)	3.81 (0.93)	4.13 (1.09)	-3.85 (2.79)	-2.56 (1.36)	1.36 (0.72)	-1.72** (2.77)	0.78 (0.58)	2.57 (2.60)
CV (%)	9.03	24.96	23.98	23.87	27.89	15.29	20.16	27.72	26.42
Tamil Nadu	-1.04 (0.95)	-0.78 (0.31)	0.28 (0.15)	-2.98 (1.78)	0.31 (0.15)	3.40 (4.51)	-0.76 (1.15)	1.42 (1.60)	2.20* (4.11)
CV (%)	9.04	16.68	12.30	18.95	17.49	17.49	14.85	23.15	24.11
Uttar Pradesh	-5.76 (2.61)	-6.69 (1.59)	-1.01 (0.29)	-0.35 (0.25)	-0.68 (0.24)	-0.64 (0.35)	-4.44** (-4.36)	-3.62 (2.60)	0.69 (0.71)
CV (%)	29.67	40.17	23.72	9.68	19.29	16.38	47.89	48.16	21.18
India	0.09 (0.22)	0.89 (0.49)	-0.79 (0.43)	-1.44 (1.33)	-1.11 (0.46)	0.32 (0.18)	-0.02 (0.05)	0.96 (1.08)	0.97 (1.54)
CV (%)	2.95	14.77	12.92	11.59	19.54	14.62	9.03	21.20	16.59

** Significant at 5% and 1% levels

Note: Figures in parenthesis indicates the t value; Growth rates are in per cent per annum; A = Area; P = Productions; Y = Yield

Table 2 Compound growth rate and coefficient of variation of area, production and yield of sesame in major states of India

State	Period-I (1971-72 to 1985-86)			Period-II (1986-87 to2002-03)			Over all period (1971-72 to2002-03)		
	A	P	Y	A	P	Y	A	P	Y
Andhra Pradesh	-2.74	-2.15	0.63	-0.92	1.04	7.46	-0.75	-0.02	0.40
	(1.02)	(0.87)	(0.32)	(0.57)	(0.23)	(0.52)	(0.96)	(0.02)	(0.10)
CV (%)	23.40	22.21	14.02	13.67	34.40	34.29	19.46	29.31	27.40
Gujarat	1.63	2.26	0.51	6.86*	14.84	7.46	4.95**	6.64*	1.59
	(0.81)	(0.40)	(0.11)	(2.80)	(1.48)	(0.95)	(5.15)	(2.08)	(0.64)
CV (%)	15.39	34.14	28.56	31.25	60.18	48.84	50.02	81.50	43.88
Madhya Pradesh	-1.39	-1.61	-0.25	-4.17	-1.74	2.52	-2.49**	-0.18	2.35
	(1.52)	(0.33)	(0.06)	(2.52)	(0.46)	(0.83)	(4.55)	(0.12)	(1.80)
CV (%)	9.13	28.25	24.83	22.39	32.04	22.26	23.44	30.08	30.91
Orissa	9.29**	9.37**	0.07	-13.59**	-20.92**	-6.89*	-2.94	-6.49	-3.13*
	(5.11)	(2.77)	(0.03)	(3.83)	(4.14)	(2.13)	(1.09)	(1.76)	(2.40)
CV (%)	14.20	47.53	14.56	82.23	14.68	47.97	63.70	82.78	35.91
Rajasthan	-0.70	-0.73	-0.06	-3.89	-0.77	2.84	-1.61	-0.27	1.36
	(0.31)	(0.10)	(0.01)	(0.91)	(0.06)	(0.29)	(1.33)	(0.07)	(0.44)
CV (%)	17.52	43.14	43.59	39.06	78.90	60.27	30.06	70.11	57.95
Tamil Nadu	0.87	0.42	1.27	-3.70*	1.05	4.82**	-0.89	1.33	2.18*
	(0.43)	(0.11)	(0.50)	(2.08)	(0.36)	(3.01)	(1.06)	(1.15)	(2.62)
CV (%)	15.09	23.14	16.08	22.31	24.43	25.72	19.11	26.58	27.43
Uttar Pradesh	-5.47	-10.31	5.25	-4.68	4.09	9.34	-6.01**	-4.65	1.45
	(1.37)	(1.45)	(0.78)	(1.64)	(1.44)	(1.78)	(5.17)	(1.97)	(0.57)
CV (%)	31.75	49.84	57.87	40.03	30.16	45.92	61.90	73.06	50.82
India	-0.26	1.80	2.07	-3.09*	-1.34	1.82	1.24*	1.06	2.33**
	(0.34)	(0.96)	(1.07)	(2.80)	(0.64)	(1.22)	(2.55)	(1.29)	(3.97)
CV (%)	5.50	14.59	15.54	18.34	19.20	15.12	14.89	21.18	24.62

** Significant at 5% and 1% levels

Note: Figures in parenthesis indicates the t value; Growth rates are in per cent per annum; A = Area; P = Productions; Y = Yield

Table 3 Compound growth rates and coefficient of variation of area, production and yield of rapeseed and mustard in major states of India

State	Period-I (1971-72 to 1985-86)			Period-II (1986-87 to2002-03)			Over all period (1971-72 to2002-03)		
	A	P	Y	A	P	Y	A	P	Y
Assam	5.78**	6.21*	0.42	-1.12*	-7.32	0.10	2.09**	0.77	0.67
	(5.98)	(2.94)	(0.26)	(-2.89)	(1.34)	(0.12)	(2.76)	(0.33)	(1.55)
CV (%)	26.95	30.57	11.70	6.72	32.75	7.32	22.78	36.55	11.23
Haryana	3.80	8.55	4.58	2.50	4.38	1.73	5.45**	9.53**	3.84**
	(0.83)	(1.46)	(1.58)	(1.02)	(1.16)	(0.68)	(4.06)	(4.98)	(3.82)
CV (%)	36.76	58.82	26.25	21.33	31.74	20.47	50.14	74.14	38.08
Madhya Pradesh	2.90	5.86	2.70	1.06	1.40	0.50	4.07**	7.11**	2.97*
	(1.32)	(0.94)	(0.69)	(0.32)	(0.32)	(0.29)	(3.37)	(3.32)	(2.67)
CV (%)	19.74	44.65	29.00	25.69	32.76	11.70	44.88	66.34	31.49
Punjab	-2.26	0.22	2.54	-5.28	-3.65	0.73	-2.68*	-0.32	2.13**
	(0.54)	(0.04)	(0.98)	(1.99)	(1.13)	(0.54)	(2.17)	(0.20)	(3.03)
CV (%)	19.74	44.65	29.00	25.69	32.76	11.70	44.88	66.34	31.49
Rajasthan	8.84	14.04	4.80	2.89	3.08	0.73	8.69**	11.35**	2.61**
	(1.85)	(2.15)	(1.32)	(0.74)	(0.73)	(0.55)	(4.72)	(4.77)	(2.78)
CV (%)	30.02	39.39	21.88	43.27	39.97	11.70	39.24	39.12	23.58
Uttar Pradesh	-3.56	-2.38	1.22	-0.85	1.16	1.70	-2.98**	-0.25	2.73
	(1.38)	(0.99)	(0.48)	(0.66)	(0.49)	(0.84)	(4.00)	(0.27)	(3.25)
CV (%)	20.54	20.02	18.62	11.48	19.57	17.36	33.87	19.56	30.11
West Bengal	6.72*	12.07*	5.05**	0.64	1.52	0.27	5.85**	9.23**	3.01
	(2.17)	(2.87)	(3.26)	(0.50)	(0.63)	(0.20)	(4.88)	(5.10)	(4.13)
CV (%)	38.09	62.86	24.65	10.96	21.15	11.02	48.72	66.78	28.92
India	-2.11	3.96	2.55	0.92	1.88	1.05	2.30	4.90**	2.80**
	(0.45)	(1.66)	(1.22)	(0.44)	(0.73)	(0.82)	(1.65)	(4.62)	(4.12)
CV (%)	22.04	23.93	18.21	17.36	20.93	11.44	30.08	46.63	26.03

** Significant at 5% and 1% levels

Note: Figures in parenthesis indicates the t value; Growth rates are in per cent per annum; A = Area; P = Productions; Y = Yield

Table 4 Compound growth rate and coefficient of variation of area, production and yield of sunflower in major states of India

State	Period-I (1971-72 to 1985-86)			Period-II (1986-87 to2002-03)			Over all period (1971-72 to2002-03)		
	A	P	Y	A	P	Y	A	P	Y
Andhra Pradesh	-6.99 (4.48)	-7.86 (0.57)	-0.81 (0.17)	5.30 (0.77)	8.67 (0.98)	3.37 (1.18)	15.34* (2.19)	17.81* (2.36)	2.14 (1.53)
CV (%)	70.19	112.91	35.43	20.89	38.30	20.33	100.39	106.50	33.00
Karnataka	23.05 (2.12)	24.82 (1.43)	3.10 (0.35)	-1.28 (0.33)	-0.51 (0.13)	0.77 (0.46)	14.39** (3.66)	13.13** (2.89)	-0.68 (0.32)
CV (%)	117.66	97.57	49.89	34.12	30.54	13.78	84.95	76.94	48.94
Maharashtra	25.91* (2.56)	27.71 (1.60)	0.11 (0.01)	-3.37 (1.27)	-4.42 (0.99)	-1.08 (0.37)	10.46* (2.60)	12.26* (2.24)	1.24 (0.50)
CV (%)	85.55	80.49	46.75	22.40	33.45	23.45	59.50	72.47	34.75
Tamil Nadu	-14.40 (1.28)	-16.5 (1.29)	-4.08 (1.02)	-4.02 (0.70)	-15.7** (2.93)	6.27** (4.72)	-5.77 (1.60)	-6.66 (1.13)	2.30 (1.53)
CV (%)	77.65	80.11	35.00	43.31	55.83	31.21	95.37	87.18	38.94
Uttar Pradesh	-3.17 (0.37)	-4.02 (0.30)	0.12 (0.05)	-0.18 (0.01)	-10.7 (1.31)	3.1.7 (1.44)	9.12 (1.74)	10.7 (1.51)	2.74* (2.56)
CV (%)	66.21	86.20	21.38	35.27	48.20	22.48	92.76	104.55	28.95
India	10.55 (1.09)	6.91 (0.73)	-3.09* (3.64)	1.20 (0.28)	2.54 (0.57)	2.32 (1.41)	11.14** (3.58)	9.66** (3.42)	-0.37 (0.49)
CV (%)	72.62	61.46	17.01	27.26	34.93	15.95	77.41	119.46	16.52

** Significant at 5% and 1% levels

Note: Figures in parenthesis indicates the t value; Growth rates are in per cent per annum; A = Area; P = Productions; Y = Yield

Table 5 Compound growth rate and coefficient of variation of area, production and yield of safflower in major states of India

State	Period-I (1971-72 to 1985-86)			Period-II (1986-87 to2002-03)			Over all period (1971-72 to2002-03)		
	A	P	Y	A	P	Y	A	P	Y
Andhra Pradesh	1.62 (0.22)	4.54 (0.54)	2.61 (0.82)	-2.71 (1.18)	-0.98 (1.18)	1.92 (1.02)	-2.48 (1.47)	-0.71 (0.35)	2.09* (2.46)
CV (%)	37.20	46.23	24.03	25.29	30.51	18.81	44.62	43.87	25.77
Karnataka	3.33 (1.71)	15.13** (3.25)	11.45* (2.67)	-6.48** (2.99)	3.69 (1.20)	3.22 (1.63)	-0.99 (0.74)	3.71 (1.62)	4.87** (3.56)
CV (%)	20.74	62.24	51.42	39.57	32.63	20.49	31.53	47.98	41.21
Maharashtra	4.25* (2.28)	9.98* (2.43)	5.51 (1.76)	-5.41* (2.70)	-5.96 (1.24)	-0.58 (0.13)	-0.80 (0.65)	0.30 (0.13)	1.11 (0.72)
CV (%)	19.00	43.43	31.56	30.76	44.41	27.49	25.38	43.43	29.62
India	3.75* (2.79)	10.57* (2.88)	6.59* (2.24)	-5.61** (3.10)	-5.17 (1.39)	0.60 (0.21)	-0.96 (0.83)	1.07 (0.52)	2.12 (1.79)
CV (%)	17.40	45.81	31.36	31.11	37.73	21.29	25.04	41.22	29.05

** Significant at 5% and 1% levels

Note: Figures in parenthesis indicates the t value; Growth rates are in per cent per annum; A = Area; P = Productions; Y = Yield

Table 6 Compound growth rate and coefficient of variation of area, production and yield of soybean in major states of India

State	Period-I (1971-72 to 1985-86)			Period-II (1986-87 to2002-03)			Over all period (1971-72 to2002-03)		
	A	P	Y	A	P	Y	A	P	Y
Madhya Pradesh	40.68**	37.56**	-2.22	8.89**	10.37*	1.41	20.61**	20.69**	0.09
	(5.98)	(5.32)	(0.93)	(3.93)	(2.27)	(0.58)	(5.89)	(6.19)	(0.10)
CV (%)	104.96	102.24	19.41	38.07	46.36	19.98	92.28	100.10	19.46
Maharashtra	NA	NA	NA	22.19**	31.00**	4.27	22.19**	31.00**	4.27
				(5.38)	(4.04)	(1.80)	(5.38)	(4.04)	(1.80)
CV (%)	NA	NA	NA	72.16	83.08	22.78	72.16	83.08	22.78
Rajasthan	46.72**	73.28*	8.95	15.57**	15.57*	0.03	21.80**	26.43**	2.08
	(3.82)	(2.76)	(1.10)	(3.88)	(2.27)	(0.01)	(5.36)	(3.99)	(1.03)
CV (%)	57.52	83.62	19.77	58.75	67.98	24.38	82.64	96.38	28.58
India	33.44**	33.60**	0.15	10.24**	12.47**	2.05	19.13**	20.38**	1.07
	(8.15)	(6.39)	(0.05)	(4.82)	(3.07)	(0.97)	(7.47)	(7.68)	(1.17)
CV (%)	98.32	97.45	20.23	42.89	50.89	18.79	95.53	104.40	20.65

** Significant at 5% and 1% levels

Note: Figures in parenthesis indicates the t value; Growth rates are in per cent per annum; A = Area; P = Productions; Y = Yield

Table 7 Compound growth rate and coefficient of variation of area, production and yield of total oilseeds in major states of India

State	Period-I (1971-72 to 1985-86)			Period-II (1986-87 to2002-03)			Over all period (1971-72 to2002-03)		
	A	P	Y	A	P	Y	A	P	Y
Andhra Pradesh	0.40	1.16	0.75	-0.48	-1.39	-0.92	1.65**	2.23	0.57
	(0.21)	(0.33)	(0.31)	(0.32)	(0.45)	(0.44)	(2.25)	(1.66)	(0.70)
CV (%)	12.98	22.80	16.03	12.61	25.62	17.62	21.77	35.12	18.15
Gujarat	2.92*	4.87	1.90	1.79	3.67	1.33	1.44*	2.75	0.56
	(2.25)	(0.65)	(0.29)	(0.95)	(0.56)	(0.33)	(2.35)	(1.75)	(0.31)
CV (%)	14.59	37.33	33.99	14.15	42.99	35.57	17.03	45.46	34.29
Karnataka	2.21	3.41	1.18	-1.69	-1.14	2.94	2.50*	3.07*	2.65
	(1.45)	(1.07)	(0.50)	(0.99)	(0.55)	(0.63)	(2.59)	(2.62)	(1.91)
CV (%)	14.38	26.34	17.71	16.84	18.08	39.30	31.05	35.37	43.50
Madhya Pradesh	1.69	4.78	3.04	4.62*	7.08	0.99	4.59**	8.57**	8.35**
	(1.26)	(1.70)	(1.64)	(2.52)	(1.85)	(0.22)	(6.40)	(6.18)	(3.06)
CV (%)	12.59	30.66	18.65	24.30	38.10	20.35	44.83	75.39	32.29
Maharastra	2.67*	6.16	3.39	0.24	4.59	3.00	1.72**	4.74**	2.28*
	(2.76)	(1.66)	(1.16)	(0.25)	(1.75)	(1.73)	(3.98)	(4.41)	(2.85)
CV (%)	12.80	29.71	20.86	7.75	26.59	20.78	17.58	43.87	25.84
Tamil Nadu	-1.59	-1.25	0.39	-3.18	0.12	2.78	-1.02	1.19	1.08
	(-1.55)	(0.51)	(0.23)	(-1.99)	(0.06)	(0.72)	(-1.58)	(1.33)	(1.18)
CV (%)	9.92	16.93	11.64	19.52	17.66	23.74	15.50	22.13	20.15
Uttar Pradesh	-3.99	-2.61	1.43	-2.35	-0.16	3.32	-4.02**	-1.20**	4.29**
	(-1.62)	(-1.07)	(0.57)	(2.83)	(0.08)	(0.93)	(6.32)	(1.51)	(3.25)
CV (%)	21.37	20.19	17.26	12.87	16.71	29.77	41.80	21.20	47.80
India	1.01*	2.59	1.57	0.71	2.23	1.50	1.65**	3.66**	1.98**
	(2.24)	(1.60)	(1.22)	(0.59)	(1.01)	(1.27)	(4.12)	(4.73)	(4.50)
CV (%)	5.49	16.02	11.03	10.23	4.33	12.03	17.79	36.73	20.56

** Significant at 5% and 1% levels

Note: Figures in parenthesis indicates the t value; Growth rates are in per cent per annum; A = Area; P = Productions; Y = Yield

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Short communication

Association between pod and kernel characteristics in valencia groundnut, *Arachis hypogaea* L. subsp. *fastigiata* var. *fastigiata*

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Groundnut (*Arachis hypogaea* L.) is classified in to four major botanical types namely Valencia bunch, Spanish bunch, Virginia bunch and Virginia runner. Among these the botanical type, Valencia bunch (*Arachis hypogaea* L. subsp. *fastigiata* var. *fastigiata*) consists of more of three kernel pods, sweet flavour and taste than other botanical forms. At United States of America, Valencia bunch varieties are grown in Eastern New Mexico State and Western Texas due to their shorter duration and suitability to the short growing period of the region. All other forms are long-duration types and hence could not be grown in the limited growing period. In the yield improvement programme of Valencia groundnut, the knowledge on association between pod and kernel characteristics would help the breeder to formulate effective selection programme. Hence an attempt has been made to assess the association among these characteristics in segregating populations of crosses involving Valencia groundnut genotypes.

Four varieties namely New Mexico Valencia A (Val A), New Mexico Valencia C (Val C), Kalina and Rossitza were used to make four direct and four reciprocal crosses. The four direct crosses are Val C x Kailna, Val A x Kailna, Val C x Rossitza and Val A x Rossitza. F_2 generation of these crosses was studied at Agricultural Research Centre at Clovis, New Mexico State, USA during May - September, 2004. Observations on pod and kernel characteristics were recorded on 200 single plants per cross (Table 1).

Number of 3-seeded pods has significant and positive correlation with total number of pods, pod yield and kernel yield in all crosses except in Kalina x Val A (Table 1). Thus, the increase in 3-seeded pods did not have any negative effect on total number of pods and pod yield. Simultaneous improvement could be brought about in pod yield and number of 3-seeded pods. Number of 3-seeded pods has significant and positive association with 100-seed weight in cross Val CxRossitza and Val AxKalina while negative association observed in reciprocal crosses. However the same trend was not observed in other combinations.

Total number of pods has positive and significant relationship with pod yield and kernel yield in all crosses. Reddy and Gupta (1992). Manoharan *et al.* (1993), Rose Mary Francies and Sethupathi Ramalingam (1997) and Salara and Gowda (1998) reported similar results.

Significant negative and positive association between number of pods and 100-seed weight was observed in crosses Rossitza x ValC and Rossitza x ValA respectively. However, non- significant association between these characteristics was observed in other crosses. Vaddoria and Patel (1992) reported significant and positive relationship between 100-seed weight and number of pods. In cross, Kailna x Val A the correlation between number of pods and shelling was significant and negative. Shelling (%) has significant and negative association with pod yield in cross Rossitza x Val C and Rossitza x Val A. The same trend was observed between shelling and 100-seed weight in cross Rossitza x Val A only. In all crosses, shelling out turn has significant and positive association with kernel yield except Rossitza x Val C. Significant and positive correlation was recorded between shelling and 100-seed weight in both direct and reciprocal crosses of Val C x Kalina and Val A x Kalina.

In case of 100-seed weight, significant and positive association was observed with pod yield and kernel yield except in Rossitza x Val C, Kalina x Val A and Val A x Rossitza. In crosses Rossitza x Val C and Kalina x Val A significant and negative association were observed between 100-seed weight and pod yield. The same trend was observed between 100-seed weight and kernel yield in cross Rossitza x Val C only. Vaddoria and Patel (1992) and Vasanthi *et al.* (1988) reported a significant and positive relationship between 100-seed weight and pod yield. Hundred seed weight was high in parents, Kalina and Rossitiza (70-90 g) and low in parents, Val A and Val C (35-40 g). This may be the reason for the differential nature of association in crosses involving Rossitza and Kalina. However, the same trend was not observed in some crosses. It indicates that the influence of large seeded parents on association of characters varies with crosses.

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Table 1 Correlation coefficients among pod and kernel characteristics in valencia groundnut

Character	Crosses in F_2 generation	Pod yield (g)	Kernel yield (g)	100-kernel weight (g)	Shelling (%)	Total number of pods
Kernel yield (g)	Val C x Kalina	0.88**				
	Kalina x Val C	0.94**				
	Val C x Rossitza	0.90**				
	Rossitza x Val C	0.95**				
	Val A x Kalina	0.96**				
	Kalina x Val A	0.80**				
	Val A x Rossitza	0.89**				
	Rossitza x Val A	0.85**				
100-kernel weight (g)	Val C x Kalina	0.26**	0.34**			
	Kalina x Val C	0.19**	0.28**			
	Val C x Rossitza	0.14*	0.18**			
	Rossitza x Val C	-0.39**	-0.43**			
	Val A x Kalina	0.20**	0.30**			
	Kalina x Val A	-0.18**	-0.03			
	Val A x Rossitza	-0.05	-0.03			
	Rossitza x Val A	0.54**	0.37**			
Shelling (%)	Val C x Kalina	0.03	0.49**	0.26**		
	Kalina x Val C	-0.10	0.24**	0.28**		
	Val C x Rossitza	-0.04	0.40**	0.09		
	Rossitza x Val C	-0.30**	0.01	0.02		
	Val A x Kalina	0.07	0.32**	0.47**		
	Kalina x Val A	-0.07	0.55**	0.16*		
	Val A x Rossitza	-0.08	0.38**	0.03		
	Rossitza x Val A	-0.15*	0.37**	-0.21**		
Total number of pods	Val C x Kalina	0.82**	0.78**	0.10	0.10	
	Kalina x Val C	0.87**	0.81**	0.06	-0.09	
	Val C x Rossitza	0.79**	0.67**	-0.05	-0.10	
	Rossitza x Val C	0.85**	0.89**	-0.51**	-0.03	
	Val A x Kalina	0.96**	0.91**	0.09	-0.03	
	Kalina x Val A	0.52**	0.17*	-0.07	-0.44**	
	Val A x Rossitza	0.76**	0.64**	-0.13	-0.12	
	Rossitza x Val A	0.93**	0.88**	0.31**	0.02	
Number of 3 seeded pods	Val C x Kalina	0.61**	0.59**	0.11	0.13	0.56**
	Kalina x Val C	0.69**	0.63**	-0.01	-0.10	0.67**
	Val C x Rossitza	0.70**	0.62**	0.17*	-0.04	0.54**
	Rossitza x Val C	0.81**	0.85**	-0.56**	-0.03	0.77**
	Val A x Kalina	0.88**	0.82**	0.23**	0.01	0.89**
	Kalina x Val A	0.69**	0.61**	-0.33**	0.06	0.13
	Val A x Rossitza	0.54**	0.58**	0.08	0.13	0.37**
	Rossitza x Val A	0.58**	0.60**	0.09	0.03	0.67**

To conclude, the increase in 3-seeded pods did not have any negative effect on total number of pods, shelling out turn, pod and kernel yield. Simultaneous improvement could be brought in these characters. However care should be taken in the selection programme when large seeded parents involved in the crosses. This necessitates formulation of separate selection indices for each cross.

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Short communication

Inter-relationship and path analysis for quantitative characters in Indian mustard, *Brassica juncea* (L.) Czern & Coss

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Mustard, *Brassica juncea* (L.) Czern & Coss is one of the most important edible oilseed as well as forage crop of India. The performance of improved varieties of Indian mustard is observed to be poor under diverse agro-ecosystems of Uttar Pradesh which forms the main traditional areas of cultivation. The rapeseed group has gone almost out of cultivation expect toria on account of its high susceptibility to pest and diseases whereas Indian mustard extensively being grown in Uttar Pradesh, Madhya Pradesh, Rajasthan, Haryana, Punjab, Bihar and West Bengal. If Indian mustard is to be grown profitably and to maximise production in Uttar Pradesh, there is an urgent need for genetic improvement to develop high yielding cultivars suitable for such circumstances.

In this regard, the knowledge of correlation between yields and its components is essential as the path coefficient analysis partitions the correlation coefficient in to direct effects indicating the relative contribution of each component to the yield. The present investigation was aimed to ascertain the inter-relationship prevalent for genetic improvement in Indian mustard.

The experimental material for the present investigation consisted of 25 diverse strains of Indian mustard *viz.*, Pusa Basant, Rohini, Varuna, Vardan, RH 819, Indra RLM 514, RLM 918, RH 7846, Vaibhav, RLM 619, TM 4, Pant Rai, RH 781, EM 6, RL 1359, EM 9, Pusa Barani, Kranti, TM 2, RH 30, Pusa Bahar, RH 8113, Pusa Bold and Parkash collected from different research centres of country. These were grown in Randomised Block Design (RBD) with three replications at the research farm of Janta Vaidic College, Baraut, Dist. Baghpat during *rabi*, 2002. Each plot consisted of five rows of 5 m length, the spacing between row to row and plant to plant was kept 30 and 15 cm, respectively. The observation were recorded on the basis of 5 randomly selected plants for 15 quantitative characters i.e., days to 50% flowering, seed filling period, days to maturity, plant height, number of primary branches, number of secondary branches, length of main shoot, number of pods on main shoot, seeds/pods, number of pods on secondary branches, number of pods on primary branches, pod length, 1000-seed weight, seed yield/plant and oil content. Correlation and path analysis was determined as per Dewey and Lu (1957).

The analysis of variance showed that there were significant differences among genotypes for all characters under study indicating the presence of adequate variability (Table 1). The analysis of genotypic correlation between the characters indicated a positive and significant correlation for seed yield/plant with number of secondary branches, 1000-seed weight, length of main shoot, number of pods on secondary branches and pod length (Table 2). This is in consonance with the findings of Tyagi *et al.* (1996); Thakaral *et al.* (1997) and Shalini *et al.* (2000). At the phenotypic level seed yield is significantly associated with number of secondary branches and 1000-seed weight in positive direction. The genotypic and phenotypic correlation coefficient among different characters revealed that in general genotypic correlations, were higher than corresponding phenotypic correlations in most characters, thereby suggesting strong inherent association between genotypic and phenotypic level. Therefore, phenotypic selection may be rewarding. Similar results were also reported (Shiekh *et al.*, 1999 and Srivastava and Singh, 2002). In some cases the phenotypic correlations were slightly higher than the genotypic correlation coefficient which may be result of modifying effect of environment on the association of the characters. The present study suggested for the improvement of Indian mustard, more emphasis need to be given for number of secondary branches, number of pods on secondary branches, length of main shoot, pod length and 1000 seed weight.

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Table 1 Mean squares for analysis of variance for 15 quantitative characters in *Brassica*

Characters/ source	Days to 50% flowering	Days to maturity	Seeds filling period	Plant height	No. of primary branches	No. of secondary branches	Length of main shoot	No. of pods on main shoot	Seeds/ pods	No. of pods on primary branches	No. of pods on secondary branches	1000-seed weight	Pod length	Oil content	Yield/ plant
Replication	3.93	3.31	0.81	65.87	0.54	4.93	84.00	7.36	4.04	86.31	109.18	7.01	0.47	0.71	33.90
Treatment	71.72**	299.38**	271.80**	826.68**	1.95*	9.95**	199.27**	72.54**	147.23**	1729.94**	2584.21**	2.80**	0.46	12.57**	222.55**
Error	2.08	2.43	3.33	49.05	0.74	1.74	72.90	17.57	24.27	104.57	62.64	0.17	0.31	2.95	15.92

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

Table 2 Genotypic and phenotypic correlation coefficient among various quantitative characters in 25 *Brassica* genotypes

Characters	Days to 50% flowering	Days to maturity	Seeds filling period	Plant height	No. of primary branches	No. of secondary branches	Length of main shoot	No. of pods on main shoot	Seeds/ pods	No. of pods on primary branches	No. of pods on secondary branches	1000-seed weight	Pod length	Oil content	Yield/ plant
Days to 50% flowering	0.000	0.330	-0.159	0.640**	0.407*	-0.149	0.168	0.084	-0.222	0.383	-0.110	0.180	0.065	-0.343	-0.220
Days to maturity		0.000	0.879**	0.401*	0.080	0.163	0.042	-0.185	-0.142	0.273	-0.090	-0.128	-0.196	-0.238	-0.296
Seeds filling period			0.000	0.098	-0.124	0.256	-0.029	-0.229	-0.031	0.099	-0.030	-0.220	-0.242	-0.077	-0.196
Plant height				0.000	0.504**	-0.079	0.484*	-0.038	-0.521**	0.565**	-0.043	0.002	-0.131	-0.769**	-0.168
No. of primary branches					0.000	-0.208	-0.417*	0.515**	-0.400*	0.548**	0.089	-0.518**	-0.620**	-0.510**	-0.489*
No. of secondary branches						0.000	0.597**	0.142	0.025	0.381	0.720**	0.111	0.173	-0.163	0.618**
Length of main shoot							0.000	0.042	-0.161	0.437*	0.459*	0.401*	0.503*	-0.395	0.490*
No. of pods of main shoot								0.000	-0.067	0.145	0.576**	-0.536**	-0.796**	0.125	-0.102
Seeds/pods									0.000	-0.084	-0.057	-0.062	0.624**	0.363	0.305
No. of pods on primary branches										0.000	-0.364	-0.142	0.047	-0.695**	0.133
No. of pods on secondary branches											0.000	-0.077	-0.410*	-0.163	0.430*
1000-seed weight												0.000	0.555**	-0.034	0.475*
Pod length													0.000	-0.372	0.634**
Oil content														0.000	-0.834**
Yield/plant															0.000

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

Table 3 Genotypic and phenotypic correlation coefficient among various quantitative characters in 25 *Brassica* genotypes

Characters	Days to 50% flowering	Days to maturity	Seeds filling period	Plant height	No. of primary branches	No. of secondary branches	Length of main shoot	No. of pods on main shoot	Seeds/ pods	No. of pods on primary branches	No. of pods on secondary branches	1000-seed weight	Pod length	Oil content	Genotypic correlation with yield/plant
Days to 50% flowering	0.372	-0.490	-0.090	0.133	0.162	-0.099	0.040	-0.035	-0.113	-0.126	-0.009	0.050	-0.008	-0.008	-0.22
Days to maturity	0.113	-0.548	0.018	0.083	0.032	0.108	0.010	0.076	-0.073	-0.090	-0.008	-0.036	0.023	-0.006	-0.30
Seeds filling period	-0.537	-0.637	0.843	0.020	-0.050	0.170	-0.007	0.094	-0.016	-0.032	-0.003	-0.062	0.029	-0.002	-0.19
Plant height	0.159	-0.027	0.669	0.208	0.201	-0.052	0.116	0.016	-0.266	-0.186	-0.004	0.000	0.016	-0.018	-0.17
No. of primary branches	0.372	-0.602	-0.851	0.105	0.399	-0.138	-0.100	-0.213	-0.205	-0.180	0.008	-0.145	0.073	-0.014	-0.49*
No. of secondary branches	-0.504	-0.232	0.751	-0.016	-0.083	0.663	0.143	-0.059	0.013	-0.125	0.061	0.031	-0.021	-0.003	0.62**
Length of main shoot	0.556	0.321	-0.199	0.101	-0.166	0.396	0.240	0.017	-0.082	-0.144	0.039	0.112	-0.060	-0.009	0.49*
No. of pods of main shoot	0.283	0.396	-0.564	-0.008	0.205	0.094	-0.010	0.413	-0.034	-0.048	0.048	-0.150	0.094	0.003	-0.10
Seeds/pods	-0.748	0.075	-0.212	-0.108	-0.160	0.017	0.039	0.028	0.512	0.028	-0.005	-0.017	-0.074	0.009	0.30
No. of pods on primary branches	0.291	-0.064	0.676	0.117	0.218	0.253	0.105	-0.060	-0.043	-0.329	0.031	-0.040	-0.006	-0.016	0.13
No. of pods on secondary branches	-0.372	0.682	-0.206	-0.009	0.036	0.477	0.110	-0.238	-0.029	-0.120	0.084	-0.021	0.048	-0.004	0.43*
1000-seed weight	0.608	0.967	-0.506	0.000	-0.206	0.073	0.096	0.221	-0.032	0.047	-0.006	0.280	-0.066	-0.001	0.47*
Pod length	0.220	0.480	-0.654	-0.027	-0.247	0.115	0.121	0.329	0.319	-0.015	-0.034	0.155	-0.118	-0.009	0.63*
Oil content	-0.156	0.793	-0.529	-0.160	-0.203	-0.090	-0.095	-0.052	0.186	0.228	-0.014	-0.004	-0.044	0.024	-0.83**

* Significant at 5% level; ** Significant at 1% level; Bold figures = Direct effect

The correlation between two characters may not necessary be the proof of direct cause of relationship as it does not indicate about the contribution of variation of one characters in relation of variations observed in the other. Path coefficient analysis was developed to study the relationship between two characters through their direct and by way of indirect influence of the other characters.

Genotypic correlations were partitioned into direct and indirect effects on seed yield/plant as indicated that among 15 characters, seed filling period exerted maximum direct effect on seed yield/plant followed by number of secondary branches, seeds/pod, number of pods in main shoot and number of primary branches (Table 3). Most of the characters manifested their indirect influence mainly through length of main shoot, number of secondary branches, number of pods on main shoot and secondary branches and oil content. This is in agreement with the findings of Tyagi *et al.* (1996), Shikrwar *et al.* (2000), Sinha *et al.* (2002) and Mahla *et al.* (2003).

Hence, the present study has clearly indicated that the weightage need to be given for days to 50% flowering, number of primary and secondary branches, seeds/pods, number of pods on main shoot for improving seed yield in Indian mustard.

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Short communication

Genetic variability for physiological and yield attributes in F_2 generation of groundnut, *Arachis hypogaea* L.

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Groundnut is the important oilseed crop of India. Though it leads in area and production in the world its productivity is low due to various abiotic and biotic stresses. Further, pod yield besides physiological traits in groundnut are quantitatively inherited complex traits and are highly influenced by environment. This necessitates a thorough knowledge of variability owing to genetic factors, actual genetic variation heritable in the progeny and the genetic advance that can be achieved through selection.

The experimental material comprised of 28 F_2 populations. The present investigation was carried out at Regional Agricultural Research Station Farm, Tirupati during *kharif* 2003. The 28 F_2s were grown in Randomized Block Design with three replications. Each entry was sown in three rows of 3 m length by adopting spacing of 30 x 10 cm. Observations were recorded on 20 competitive plants selected at random for 13 characters (Table 1). The phenotypic and genotypic coefficient of variations were computed according to Burton (1952). The heritability in broad sense was computed as suggested by Allard (1960) and genetic advance as percentage of mean as per Johnson *et al.* (1955).

Analysis of variance revealed significant differences among the crosses for all the characters studied indicating presence of a high degree of variability. The estimates of variability parameters are given in Table 1. Narrow differences between phenotypic coefficient of variation and genotypic coefficient of variation were observed for all the characters except root length, number of well filled and mature pods/plant, kernel yield/plant and pod yield/plant indicating the little influence of environment on expression of these characters. High genotypic coefficient of variation and phenotypic coefficient of variation was observed for specific leaf nitrogen. Selection for this would facilitate the successful isolation of drought tolerant genotypes. Similar results for specific leaf nitrogen was reported by Bindhu Madhavi *et al.* (2003). The study of genotypic coefficient of variation also revealed that all other characters except specific leaf nitrogen showed narrow genetic variability and thereby offering a limited opportunity to improve further these characters.

High heritability along with high genetic advance as per cent of mean in character suggests that the genotypic variation for such character is probably due to high additive genetic effects, environmental effects had least influence on such characters. High heritability coupled with high genetic advance as per cent of mean were observed for per cent reduction of Fv/Fm, specific leaf area, specific leaf nitrogen, sound mature kernel per cent, harvest index and shell thickness. Reddy and Gupta (1992) and Vasanthi and Raja Reddy (2002) in groundnut reported similar results. However, pod yield/plant and number of mature pods recorded low heritability. Seethala Devi (2004) also reported high heritability and high genetic advance as per cent of mean for harvest index. Non-additive and additive based interactions could be associated with characters possessing high heritability coupled with moderate genetic advance as per cent of mean.

The characters, SPAD chlorophyll meter reading, oil per cent, shelling per cent and kernel yield/plant had low genetic advance as per cent of mean values and had moderate heritability values indicating lesser proportion of genotypic components in the total variability. This suggests that the characters might be controlled by both additive and non-additive gene and selection based such characters may be effective to some extent. Rostini *et al.* (2000) reported low heritability and genetic advance as per cent of mean for SPAD chlorophyll meter reading. Low heritability and low genetic advance as per cent of mean was observed for characters *viz.*, root length, number of well filled and mature pods/plant and pod yield/plant indicating that these characters are controlled by non-additive gene action and selection for improvement of such characters would not effective. Low heritability and low genetic advance as per cent of mean for root length was reported in groundnut by Makhan Lal *et al.* (2003).

It is evident that for genetic improvement of per cent reduction of Fv/Fm, specific leaf area, harvest index, sound mature kernel per cent and shell thickness characters, selection would be very effective.

Table 1. Estimates of genetic parameters for thirteen characters in 28 F_2s of groundnut

Character	Mean	PCV (%)	GCV (%)	h^2	GA	GAM
SPAD chlorophyll meter reading	44.55	4.74	3.26	0.47	1.99	4.48
Specific leaf nitrogen (g N/m^2)	1.97	27.68	27.25	0.90	1.01	51.43
Specific leaf area (cm^2/g)	163.33	17.58	16.81	0.91	54.11	33.13
Per cent reduction of Fv/Fm	50.65	22.04	20.39	0.97	22.67	44.75
Root length (cm)	20.99	13.38	6.07	0.20	1.19	5.68
Harvest index	0.42	15.05	12.87	0.73	0.10	22.67
Shell thickness (mm)	1.09	11.29	10.15	0.81	0.21	18.79
Oil (%)	41.39	7.07	4.63	0.43	2.59	6.24
Shelling (%)	66.48	8.97	6.41	0.55	6.29	9.45
Sound mature kernel per cent	66.38	13.96	12.71	0.83	15.82	23.29
Number of well filled and mature pods/plant	10.56	17.37	8.06	0.21	0.81	7.71
Kernel yield/plant (g)	5.92	18.47	10.93	0.35	0.79	13.33
Pod yield/plant (g)	9.15	18.31	6.91	0.14	0.49	5.38

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Short communication

Induced variability for glucosinolate content in Indian mustard, *Brassica juncea* (L.) Czern & Coss

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Glucosinolates are a group of plant thioglucosides found principally among the members of family *Brassicae*. The vegetative tissue and seed of *Cruciferous* contain one or more of the 120 known glucosinolates (Fenwick *et al.*, 1983). Glucosinolates co-exist with an enzyme called myrosinase which mediates their breakdown to a range of active compounds, isothiocyanates, nitiriles and oxazolidimethiones which render the seed meal unsuitable for use as animal feed, especially for non-ruminants (poultry and piggery). The toxicity manifestation of these products is goiter, as a result of iodine uptake impairment, liver damage, increased liver weight, reduced body weight and food intake occur in farm animals. The presence of high glucosinolates in seed meal of Indian cultivars of rapeseed-mustard is a strong non-tariff barrier in international market and fetches low prices. Realizing the importance of the problem concerted efforts were intensified in India under the aegis of "National Network on Improvement of Quality of Oilseed Brassicas" to reduce the glucosinolates content of Indian mustard varieties up to the internationally accepted norms (Chauhan *et al.*, 2002). BJ-1058, an exotic strain was the only source of low glucosinolate in *B. juncea* available until recently. This strain has moderate glucosinolate content (45-50 µg/g defatted seed meal) under Indian conditions and extensively utilized in the breeding programme to transfer gene(s) in the genetic background of high yielding Indian mustard varieties, PCR-7, Pusa Bold, Kranti, RL-1359 and Bio-902. These efforts led to the development of many lines with reduced glucosinolate content in the range of 50-60 µm/g defatted seed meal (Anonymous, 2004; Chauhan *et al.*, 2004). Keeping this in view, the present investigation was undertaken to induce variability for glucosinolate content in the parental line has been BJ-1058 (yellow and brown seeded) and a line derived from this parent possessing moderate glucosinolate content using ethyl methane sulphonate (EMS) and gamma irradiations.

The selfed seeds of BJ-1058 (48-52 µmole/g defatted seed meal) and advance breeding line BPR-47-189-5 (46 µmole/g defatted seed meal) were irradiated with gamma radiations (40, 60, 80, 120 kR) using ^{60}Co source and also treated with aqueous solution of EMS (0.2 and 0.5% for 4 hrs) at seed moisture content of 7-8% (BJ-1058) and 12% (BPR-47-189-5). The M_1 generation was raised during 2000-01. A composite sample of selfed-seeds from M_1 plants was used to raise the M_2 generation during 2001-02. Both the selfed and open-pollinated seeds from about 4500 M_2 plants across different treatments were harvested. The glucosinolate content of open pollinated seeds from each plant was analyzed following sodium tetrachloropalladate method by ELISA reader at 405 nm (Kumar *et al.*, 2004) and expressed as µmole/g defatted seed meal. The oil (%) and protein content (%) of selected plants was analysed by NIR (Dickey John, Instalab-600 product analyzer). The range, mean and coefficient of variability were computed to assess the variability.

The number of M_2 plants analysed for glucosinolate content varied from as low as 9 for the treatment when BJ-1058-12-5-7 was irradiated with 40 k R as well as treated with 0.5% EMS (T_{32}) to 517 for the treatment BJ-1058-12-2-3 treated with 120 k R (T_7). The glucosinolate content among the plants in the T_8 had the maximum range of 43.7-167.7 µmoles with an over all mean of 74.3±2.8. The coefficients of variation varied from 1.3 (T_{22})-30.4% (T_{26}) indicating variability for glucosinolate content in different treatments. The variability was low in T_{22}, T_{31} and T_{34}. In rest of the treatments, the variability was, by and large, moderate. The M_2 plants obtained by irradiating BPR 47-189-1-5 with 80 k R ± 0.2% EMS (T_{26}) showed the maximum variation (Table 1). Because of the very small sample size of 21 and 42 plants in T_{22} and T_{31}, the glucosinolate content varied the least. The glucosinolate content across the treatments varied from 33.7-167.7 µmoles/g defatted seed meal with an overall mean of 61.7±0.1 µmoles. The mean glucosinolate content among different treatments ranged from 51.9 (T_{28})-82.4 (T_{33}) µmoles/g defatted seed meal (Table 1). The mean glucosinolate content was about 55 µmole/g defatted seed meal in T_6, T_7, T_{17}, T_{18}, T_{21}, T_{28}, T_{30}, T_{31} and T_{32}. Of the total, 4,542 M_2 plants, only 51 plants (1.1%) had glucosinolate content ranging between 33-40 µmoles. The majority of

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the plants, 34.5% and 26.8% showed glucosinolate content in the range of 51-60 and 41.50 μmoles, respectively (Fig.1) whereas, only 3.3% plants had >100 μmoles.

Gene pool comprising 359 M_2 plants having glucosinolate content upto 45 μmoles was characterized for oil, protein content and 1000-seed weight. The oil content varied from 32.7 to 44.5% whereas protein content ranged between 14.8-23.1%. A range of variation (2.4-3.4 g) was observed for 1000-seed weight. Further, 37 M_2 plants with <40 μmoles of glucosinolate were selected. The glucosinolate content of the selected plants varied from 30.0-40.0 with mean of 38.6±0.2 μmoles (CV 3.7%). The oil and protein content had a range of 35.6-41.7% with a mean of 38.4±0.2 (CV 3.8) and 14.8-21.9% with a mean of 19.5±0.2 (CV 3.5%), respectively. The moderately low glucosinolates containing plants will be further selected for agronomic characters. The present investigation provided a valuable gene pool of variable and reduced glucosinolate content as compared to the parental lines. Some of the plants were close to the desirable level of 30 μmoles (Table 2). Nevertheless, recently Indian mustard lines with low glucosinolate content as well as double low characteristics have been registered in India (Anonymous, 2004).

Table 1 Range, mean and coefficient of variability (CV %) in M_2 generation for glucosinolate content in Indian mustard

Treatment	Treatment	Dose(s)	Range	Mean ± SEm	CV (%)
T_1	BJ 1058 12-2-3	0	50.3-58.8	54.7±0.7	6.1
T_2	BJ 1058 12-5-7	0	48.0-53.0	50.2±0.4	3.0
T_3	BPR 47-189-1-5	0	46.3-58.3	50.5±0.6	7.6
T_4	BJ 1058 12-2-3	40 k R	37.2-113.8	59.8±1.0	28.3
T_5	BJ 1058 12-2-3	60 k R	40.1-101.3	60.5±1.2	25.7
T_6	BJ 1058 12-2-3	80 k R	40.1-84.6	55.7±1.7	21.7
T_7	BJ 1058 12-2-3	120 k R	38.4-107.7	55.6±0.6	23.3
T_8	BJ 1058 12-5-7	40 k R	43.7-167.7	74.3±2.8	30.3
T_9	BJ 1058 12-5-7	60 k R	45.2-85.4	62.9±4.5	24.0
T_{10}	BJ 1058 12-5-7	80 k R	41.2-123.1	81.3±2.3	25.5
T_{11}	BJ 1058 12-5-7	120 k R	143.0-107.7	70.1±4.6	28.2
T_{12}	BPR 47 189-1-5	40 k R	42.8-127.0	66.1±1.0	22.6
T_{13}	BPR 47 189-1-5	60 k R	39.4-115.7	71.2±1.5	26.0
T_{14}	BPR 47 189-1-5	80 k R	39.8-127.4	67.5±1.2	24.4
T_{15}	BPR 47-189-1-5	120 k R	39.2-107.7	79.7±2.7	20.5
T_{16}	BJ 1058 12-2-3	40 k R + 0.2%	44.6-99.1	65.1±1.4	24.5
T_{17}	BJ 1058 12-2-3	60 k R + 0.2%	39.6-101.9	54.7±0.7	20.3
T_{18}	BJ 1058 12-2-3	80 k R + 0.2%	38.8-96.1	52.3±1.2	23.4
T_{19}	BJ 1058 12-2-3	120 k R + 0.2%	41.3-108.0	61.5±1.4	28.7
T_{20}	BJ 1058 12-5-7	40 k R + 0.2%	46.5-116.0	64.5±3.0	21.4
T_{21}	BJ 1058 12-5-7	60 k R + 0.2%	42.8-83.4	54.7±1.6	19.1
T_{22}	BJ 1058 12-5-7	80 k R + 0.2%	45.9-77.0	63.0±1.7	1.3
T_{23}	BJ 1058 12-5-7	120 k R + 0.2%	48.0-83.0	62.7±3.3	17.4
T_{24}	BPR-47 189-1-5	40 k R + 0.5%	38.9-114.6	60.6±1.0	25.4
T_{25}	BPR-47 189-1-5	60 k R + 0.5%	40.7-116.5	64.2±1.5	28.4
T_{26}	BPR-47 189-1-5	80 k R + 0.5%	39.8-130.0	72.5±1.7	30.4
T_{27}	BPR-47 189-1-5	120 k R + 0.5%	45.7-82.2	60.4±2.8	19.5
T_{28}	BJ 1058 12-2-3	40 k R + 0.5%	39.3-94.4	51.9±1.5	18.4
T_{29}	BJ 1058 12-2-3	60 k R + 0.5%	40.3-103.2	61.7±1.2	24.5
T_{30}	BJ 1058 12-2-3	80 k R + 0.5%	33.7-149.5	54.7±0.6	23.0
T_{31}	BJ 1058 12-2-3	120 k R + 0.5%	40.6-88.7	52.7±1.7	1.8
T_{32}	BJ 1058 12-5-7	40 k R + 0.5%	40.3-64.0	53.8±2.9	16.2
T_{33}	BJ 1058 12-5-7	60 k R + 0.5%	49.6-107.7	82.4±3.2	19.1
T_{34}	BJ 1058 12-5-7	80 k R + 0.5%	58.0-74.0	64.0±1.8	9.4
T_{35}	BJ 1058 12-5-7	120 k R + 0.5%	40.2-99.1	61.5±2.2	26.2
T_{36}	BPR-47 189-1-5	40 k R + 0.5%	39.5-115.0	61.2±0.9	24.8
T_{37}	BPR-47 189-1-5	60 k R + 0.5%	40.2-106.4	59.6±1.1	23.9
T_{38}	BPR-47 189-1-5	80 k R + 0.5%	41.6-118.0	69.0±0.9	23.1
T_{39}	BPR-47 189-1-5	129 k R + 0.5%	41.8-118.8	65.0±3.5	27.3

Table 2 Characterization of selected plants having <40 µmole/g defatted seed meal

Identification	Glucosinolate content*	Protein content (%)	Oil content (%)	1000-seed weight (g)
BJ 1058-12-2-1-38-24	32.1	18.5	36.7	2.9
BJ 1058-12-2-1-35	31.9	19.4	39.6	2.8
BPR-47-324-2-143-13	30.0	22.7	38.1	3.5
BJ 1058-12-2-1-38-12	32.9	21.4	39.0	2.8
BJ 1058-12-2-1-38-5	33.0	21.7	37.9	2.9
BJ 1057-12-2-3-183	37.0	18.7	38.7	3.0
BJ 1058-12-2-3-90	38.0	20.5	37.1	2.8
BPR-47-189-1-5-214	39.5	20.2	37.2	3.9
BJ 1058-12-2-3-371	37.4	19.0	39.9	4.0
BJ 1058-12-2-3-379	37.4	18.4	40.3	3.7
BPR-47-189-1-5-158	39.0	19.2	41.3	4.1

* µmoles/g defatted seed meal

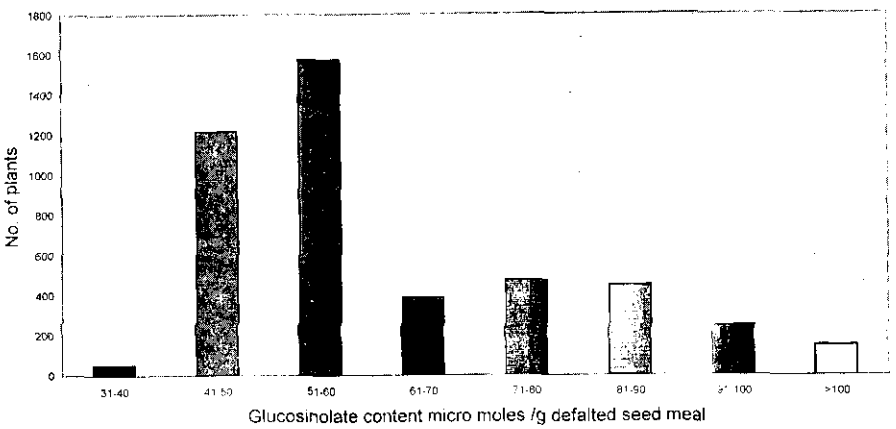

Fig.1. Classification of M_2 plants on the basis of glucosinolate content

Variability for glucosinolate content was induced using gamma radiations (40, 60, 80 and 120 k R) and ethyl methane sulphonate (0.2 and 0.5% for 4 hrs) in three parental lines, *BJ 1058-12-2-3, BJ 1058-12-5-7 and an* advance breeding line BPR 47-189-1-5 having moderate glucosinolate content (46-52 µmoles/g defatted seed meal) during 2001-02. The 4,542 M_2 plants from different treatments (T_1-T_{39}) were analysed for glucosinolate content by palladium complex method and measuring the colour intensity of the complex by ELISA reader at 405 nm. The glucosinolate content in the M_2 generation ranged from 33.7-167.7 µmoles/g defatted seed meal as compared to control BJ 1058-12-2-3 (52 µmoles), BJ 1058 12-5-7 (48 µmoles) and BPR-47-189-1-5 (46 µmoles), respectively. Fifty one plants (1.1%) had glucosinolate content ranging from 33-40 µmoles. The majority of the plants (34.5%) showed glucosinolate content in the range of 51-60 µmoles. The glucosinolate, oil, protein content and 1000-seed weight of 359 moderate glucosinolate (<45 µmoles) containing plant are discussed in this paper and characteristics of 10 plants having 30-40 µmoles of glucosinolate are also presented. The seed weight of the selected plants is quite low, nevertheless, a few had comparable oil content with the parental lines.

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Short communication

Stability analysis for yield and its components in mustard, *Brassica juncea* (L.) Czern & Coss

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Mustard is an important oilseed crop grown in India. There are great fluctuations in its productivity together with low yield level in Jharkhand. Amongst various causes, its environmental sensitive and unstability under different environmental conditions are considered to be the foremost. Therefore, the present study was undertaken to identify stable, early maturing and high yielding varieties of mustard that could fit in various agro-climatic regions of Jharkhand.

The experimental material comprised 19 diverse genotypes of mustard including Pusa Bold, Varuna and BR 40. These genotypes were grown in Randomized Block Design with three replications over four years, during winter 1998-99 to 2001-02 under limited irrigated conditions at Zonal Research Station, Darisai. A plot comprised of five rows of 5 m length distance between rows and plant was maintained as 30 cm and 10 cm, respectively. Observations on nine quantitative characters *viz.*, days to 50% flowering, days to maturity, plant height, primary branches/plant, secondary branches/plant, siliquae/plant, seeds/siliqua, seed size (g) and seed yield (kg/ha) were recorded. Data related to seed yield was recorded on plot basis while remaining characters were noted on five random plants/plot. Stability parameters were estimated as per Eberhart and Russell (1966).

The mean square due to genotypes x environments (GxE) interactions were significant for all the traits when tested against pooled error implying differential behaviour of genotypes under varied environments (Table 1). These results were in accordance with the findings of Kumar *et al.* (1991), Thakur *et al.* (1992), Patel *et al.* (1997) and Thakur *et al.* (1997).

The mean squares due to varieties, when tested against pooled deviation, were highly significant for days to 50% flowering, days to maturity, 1000-seed weight and seed yield and significant for plant height. E+(GxE) was significant for days to maturity and highly significant for days to 50% flowering, plant height and secondary branches/plant. The partitioning of environment + genotype x environment interaction into different components revealed that the environment (linear) was significant for all the traits indicating considerable difference among environments and its predominant effect on all the traits. Significant linear component of genotypes x environment interaction for all the characters suggested that the genotypes differed for their linear response to environments. However, the pooled deviation from regression were also significant for all the traits except primary branches/plant, but the magnitude of linear components were higher in comparison to pooled deviation indicating thereby that major portion of interaction was linear in nature and prediction over the environments for these attributes was still possible. Similar results were reported by Kumar *et al.* (1991) and Thakur *et al.* (1997). The mean ($\bar{x}$), regression coefficient (b_i) and deviation from regression (S^2di) for different characters are presented in Table 2.

Table 1 Analysis of variance for stability in mustard mean sum of square

Source	d.f.	Days to 50% flowering	Plant height (cm)	Days to maturity	No. of primary branches/ plant	No. of secondary branches/ plant	No. of siliquae/ plant	No. of seeds/ siliqua	1000-seed weight (g)	Seed yield (kg/ha)
Genotype (G)	18	22.18**++	72.73**+	67.81**++	0.25*	0.71**	443.71**	0.77**	0.40**++	16074.40**++
Environment (E)	3	690.54**++	4654.73**+	57.06**++	0.86**++	22.43**++	12420.38**	1.06**	2.35**++	39744.36**++
G x E	54	4047**+	44.18**	10.16**	0.21*	0.77**	291.08**	0.45**	0.10**	5655.61**
E + (G x E)	57	40.58**++	286.84**++	12.63**+	0.25*	1.91**++	229.46**	0.48**	0.22**	7449.75**
Environment (linear)	1	2071.63**++	13964.20**++	171.19**++	2.57**++	67.78**++	37261.15**++	3.17**++	7.05**++	119233.09**++
G x E (Linear)	9	13.42**++	132.54**++	30.48**++	0.64**++	2.30**++	873.24**++	1.33**+	0.30**	10829.27**
Pooled deviation	38	2.40**	38.14**	6.83**	0.16	0.75**	290.65**	0.55**	0.17**	5995.88**
Pooled error	152	0.47	30.47	0.63	0.13	0.30	124.75	0.20	0.032	1316.02

*, ** = Significant at 5% and 1% level respectively (pooled error); +, ++ = Significant at 5% and 1% level, respectively (pooled deviation)

Table 2 Estimates of stability parameters for nine characters in mustard

Genotype	Days to 50% flowering			Days to maturity			Plant height (cm)			No. of primary branches/plant			No. of secondary branches/plant		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
BAUR 9101	47.00	0.96	0.93	108.92	-0.64	2.91	145.59	0.71	-5.34	4.60	2.27	-0.01	5.52	0.09	0.12
BAUR 9112	43.33	1.48	0.43	104.08	-0.72	32.88	148.70	1.62	-29.95	4.33	-0.12	-0.03	5.55	0.71	-0.11
BAUR 9113	49.50	0.98	2.36	110.08	-0.74	2.73	149.33	1.03	25.82	4.22	2.48	-0.01	5.02	1.21	0.13
Varuna	49.00	0.93	2.05	111.92	0.32	0.74	148.80	0.55	46.40	4.43	4.01	-0.09	5.10	1.34	0.21
BAUR 9114	47.17	0.83	0.41	106.58	0.06	-0.62	149.97	1.10	-25.73	4.80	1.94	0.04	5.77	1.35	-0.06
Pusa Bold	46.75	1.10	0.74	105.25	-0.14	3.44	153.08	0.82	-14.15	4.07	2.11	-0.10	5.03	0.97	-0.26
BAUR 9115	44.08	1.08	1.86	104.50	2.62	26.79	145.42	1.24	12.94	4.33	-0.37	-0.06	4.88	0.37	0.01
BR 40	46.33	0.62	2.79	101.42	1.76	8.26	146.98	0.60	-9.64	4.33	0.64	-0.01	5.53	1.43	-0.19
BAUR 9510	43.17	1.48	3.95	98.58	1.05	5.74	145.20	0.97	44.82	4.32	0.54	-0.00	4.93	1.08	2.14
BAUR 9503	43.08	1.24	0.69	99.00	1.51	6.14	140.52	1.13	4.00	3.82	0.11	0.09	4.30	0.81	0.39
BAUR 9508	44.67	1.28	0.92	101.92	1.66	1.66	152.33	0.84	-26.09	4.41	1.62	-0.11	5.60	1.28	-0.13
BAUR 9505	46.50	1.17	1.96	107.25	-0.59	0.53	142.48	1.27	73.58	4.37	-0.72	0.03	5.50	0.08	-0.15
BAUR 9512	43.67	1.10	0.64	103.17	1.47	1.50	148.28	1.26	79.69	3.93	0.62	-0.02	6.10	0.56	4.96
BAUR 9507	47.08	0.58	0.48	107.08	3.20	1.58	154.47	1.15	15.81	4.72	-2.17	-0.03	5.78	0.98	-0.11
BAUR 9509	43.58	0.70	0.02	101.00	2.68	10.65	149.40	0.67	14.58	4.20	1.78	0.09	5.28	1.01	0.37
BAUR 9502	41.42	1.21	-0.09	98.67	1.76	4.35	154.88	1.01	6.37	4.38	3.35	-0.10	4.90	1.38	-0.01
BAUR 9506	41.42	0.92	-0.01	98.33	1.73	1.05	145.98	0.98	-24.10	4.02	0.66	0.12	4.97	0.69	-0.29
BAUR 9501	46.17	0.83	7.80	103.42	2.63	6.22	156.80	1.11	-15.83	4.53	0.59	0.06	5.45	1.04	0.27
BAUR 9504	46.83	0.70	2.75	108.17	-0.66	1.13	151.45	0.91	31.53	4.28	0.66	0.41	5.28	1.61	1.34
Population mean	45.30	1.00	-	104.18		-	148.93	1.00	-	4.31	0.59	-	5.29	1.00	-
SEm±	1.22	0.20	-	1.84		-	3.84	0.25	-	0.27	-0.35	-	0.51	0.47	-

Table 2 (Contd...)

Genotype	No. of siliquae/plant			No. Of seeds/siliqua			1000-seed weight (g)			Seed yield (kg/ha)		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
BAUR 9101	131.63	0.82	45.56	10.31	1.76	0.08	145.59	0.71	-5.34	4.60	2.27	-0.01
BAUR 9112	43.33	1.48	0.43	104.08	-0.72	32.88	148.70	1.62	-29.95	4.33	-0.12	-0.03
BAUR 9113	49.50	0.98	2.36	110.08	-0.74	2.73	149.33	1.03	25.82	4.22	2.48	-0.01
Varuna	49.00	0.93	2.05	111.92	0.32	0.74	148.80	0.55	46.40	4.43	4.01	-0.09
BAUR 9114	47.17	0.83	0.41	106.58	0.06	-0.62	149.97	1.10	-25.73	4.80	1.94	0.04
Pusa Bold	46.75	1.10	0.74	105.25	-0.14	3.44	153.08	0.82	-14.15	4.07	2.11	-0.10
BAUR 9115	44.08	1.08	1.86	104.50	2.62	26.79	145.42	1.24	12.94	4.33	-0.37	-0.06
BR 40	46.33	0.62	2.79	101.42	1.76	8.26	146.98	0.60	-9.64	4.22	0.64	-0.01
BAUR 9510	43.17	1.48	3.95	98.58	1.05	5.74	145.20	0.97	44.82	4.32	0.54	-0.00
BAUR 9503	43.08	1.24	0.69	99.00	1.51	6.14	140.52	1.13	4.00	3.82	0.11	0.09
BAUR 9508	44.67	1.28	0.92	101.92	1.66	1.66	152.33	0.84	-26.09	4.41	1.62	-0.11
BAUR 9505	46.50	1.17	1.96	107.25	-0.59	0.53	142.48	1.27	73.58	4.37	-0.72	0.03
BAUR 9512	43.67	1.10	0.64	103.17	1.47	1.50	148.28	1.26	79.69	3.93	0.62	-0.02
BAUR 9507	47.08	0.58	0.48	107.08	3.20	10.65	154.47	1.15	15.81	4.72	-2.17	-0.03
BAUR 9509	43.58	0.70	0.02	101.00	2.68	4.35	149.40	0.67	14.58	4.20	1.78	0.09
BAUR 9502	41.42	1.21	-0.09	98.67	1.76	1.05	154.88	1.01	6.37	4.38	3.35	-0.10
BAUR 9506	41.42	0.92	-0.01	98.33	1.73	6.22	145.98	0.98	-24.10	4.02	0.66	0.12
BAUR 9501	46.17	0.83	7.80	103.42	2.63	1.13	156.80	1.11	-15.83	4.53	0.59	0.06
BAUR 9504	46.83	0.70	2.75	108.17	-0.66	-	151.45	0.91	31.53	4.28	0.66	0.41
Population mean	45.30	1.00	-	104.18		-	148.93	1.00	-	4.31	0.59	-
SEm±	1.22	0.20	-	1.84			3.84	0.25	-	0.27	-0.35	-

An ideal variety is one with high mean performance *average responsiveness to environment (b=1.0) and* stability over environments (S^2d_i=0). According to Eberhart and Russell (1966) if a genotype has non-significant S^2d_i *(deviation from regression), performance may be* predictable. They have also advocated that a stable variety is one which should perform relatively better under *adverse conditions and not so well in favourable* environment.

Out of 19 genotypes tested, two genotypes BAUR 9506 and BAUR 9509 expressed stability under unfavourable environment for days to 50% flowering since their regression coefficient (b_i) were below unity (<1=0) and deviation from regression (S^2d_i) was non-significant. Four genotypes *viz.*, BAUR 9502, BAUR 9503, BAUR 9508 and BAUR 9512 showed stability under favourable environment because their coefficient of regression (b_i) were greater than unity (>1=0) and S^2d_i was non-significant for days to maturity only one genotype i.e., BAUR 9506 exhibited stability under favourable environment.

For plant height *Pusa Bold, BAUR 9504 and BAUR 9509* achieved above average stability under poor environmental conditions since their b_i values were less than one whereas, *BAUR 9502 and BAUR 9113* showed average stability in all types of environments (bi=1.0) and the genotypes BAUR 9501, BAUR 9507 and BAUR 9114 were found stable under favourable environments (b_i=>1.0).

With respect to primary branches/plant the genotypes BAUR 9501, BAUR 9505 and BAUR 9507 expressed high stability under adverse conditions (b_i=<1) while, four *genotypes viz.*, BAUR 9101, BAUR 9114, BAUR 9502 and BAUR 9508 exhibited stability under favourable environment (b_i=>1). For secondary branches/plant, the *genotypes BAUR 9509 and BAUR 9507 showed above* average stability in all types of environments because their coefficient of regression was nearer to unity and the *genotypes BAUR 9112, BAUR 9505 and BAUR 9101 were* suitable under poor environment while BAUR 9114, BR 40 and BAUR 9501 appeared adopted to favourable *conditions.*

The genotypes BAUR 9101 and BAUR 9507 showed above average stability for siliquae/plant in unfavourable environment while other four genotypes *viz.*, BAUR 9112, BAUR 9114, BAUR 9506 and BAUR 9509 exhibited stability under favourable environment with high mean values. Although BAUR 9501 possessed the highest mean value for siliquae/plant but its deviation from regression *(S^2d_i) was significant. For seeds/siliqua* BAUR 9501, BR 40, BAUR 9502, BAUR 9504 and BAUR 9508 did well under unfavourable environment. Above average stability *under adverse environment was exhibited* by the genotypes BAUR 9113, Varuna, Pusa Bold, BAUR 9501, BAUR 9507 and BAUR 9508 for 1000 seed weight as *expected and a genotype BAUR 9112 did well only* under well only under favourable environment.

Five genotypes showed stability and adaptability in yield performance with high mean values. Of these, Pusa Bold exhibited average stability in all types of environments. Two genotypes i.e., BAUR 9507 and BAUR 9509 produced better stability under poor environment whereas, BAUR 9114 and BAUR 9501 were found adoptable under favourable environmental conditions. Although the genotypes BAUR 9506, BAUR 9510, BAUR 9504, Varuna and BAUR 9502 were produced higher seed yield in comparison to population mean but their deviation from regression were found significant. The rest of the genotypes were low yielder and unstable.

The genotypes *viz., BAUR 9114, BAUR 9501 and BAUR* 9507 were observed stable for most of the characters related to high seed yield. Although Pusa Bold and BAUR 9509 were stable only for a few characters, these produced the high and stable seed yield. Thus, these genotypes can be suggested for commercial cultivation in wide range of environmental conditions and can be used in further breeding programme.

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Short communication

Exploitation of heterosis in sunflower, *Helianthus annuus* L.

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Sunflower is one of the most important edible oilseed crops in India and being a cross pollinated crop, it offers considerable scope for commercial exploitation of heterosis utilising cyto-restorer system (Sugoor *et al.*, 1996; Gangappa *et al.*, 1997). All the presently grown commercial hybrids posses the PET-1 cytoplasm. Diversification of CMS source is inevitable in any heterosis breeding programme as the use of single CMS source involves a potential risk if it is becoming susceptible to a new strain of disease. Fortunately in sunflower, several new sources of CMS lines have been reported (Anashchenko and Kukosh, 1984). 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 the above, facts the present investigation was taken upto study the extent of heterosis using diverse cytoplasmic sources and their effective restorers.

The experimental material comprised of four CMS lines belonging to two different CMS sources, *Helianthus petiolaris* (CMS 7-1 and CMS 335) and *Helianthus argophyllus* (DCMS 41 and DCMS 42) were crossed with 14 common restorers used as testers in the L x T design and two hybrids MSFH-17 and KBSH-1 were used as standard checks. These 56 crosses along with their parents were grown in Randomised Block Design with three replications.

The experiment was conducted at Directorate of Oilseeds Research, Rajendranagar, Hyderabad. Crossing was carried out during *kharif*, 2003 and evaluation of crosses and their parents was done during *rabi*, 2003-04. Each entry was grown in two rows with a length of 3 m, with a spacing of 60 cm x 30 cm. Standard package of practices were followed for raising the crop. Data were recorded on 11 different traits and subjected to statistical analysis. The per cent heterosis over mid parent, over better parent and standard heterosis were estimated.

Heterosis was estimated for the 56 hybrids for 11 different characters and was expressed as increase or decrease over mid parental value, heterosis over better parent, heterobeltiosis and over standard check, standard heterosis (Table 1).

For days to 50% flowering and days to maturity, heterosis in negative direction is considered desirable since earliness is preferred over late maturity, the hybrid DCMS 42 x DSI 729 recorded highest significant negative heterosis (-13.33) for days to 50% flowering and days to maturity (-8.14). Wali *et al.* (1995) and Ravinder (2001) have reported positive heterosis for days to 50% flowering in hybrids.

The cross DCMS 41 x DSI 680 (-28.96) recorded highest negative heterosis and heterobeltiosis, while, DCMS 42 x DSI 725 (59.55) recorded highest positive heterosis/plant height. Nineteen hybrids exhibited positive significant standard heterosis for stem diameter over KBSH-1 and 17 hybrids over MSFH-17.

For head diameter, 12 hybrids, out of 56 hybrids have shown significant positive heterosis which is ranged from -31.47 (DCMS-42 x DSI 716) to 59% (CMS 335 x DSI 743). Seven hybrids have shown significant positive heterobeltiosis. While significant positive standard heterosis was shown by nine hybrids over KBSH-1, none of the hybrids shown significant positive standard heterosis over MSFH-1.

For number of filled seeds/head, most of the crosses have shown significant positive heterosis, heterobeltiosis and standard heterosis. The cross combinations which recorded higher heterosis per cent over mid parent were CMS 335 x DSI 732 (77.99), CMS 7-1 x DSI 743 (58.59) and CMS 335 x DSI 729 (50.19). For 100-seed weight 15 hybrids have shown significant heterosis, while six hybrids shown positive heterobeltiosis and five hybrids shown standard heterosis. The hybrid DCMS 42 x DSI 728 showed highest positive heterosis (64.08) and heterobeltiosis (48.00) for oil content.

Heterosis in negative direction was considered desirable for plant height. Among 56 hybrids, 31 hybrids have shown significant positive heterosis, while six hybrids have shown significant negative heterosis.

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Table 1 Per cent heterosis (h1), heterobeltiosis (h2) and standard heterosis (h3) over MSFH-17 and KBSH-1 for yield and its component characters in sunflower in best selected hybrids

Character	Hybrid	Heterosis (%)	Heterobeltiosis (%)	Standard heterosis	
				MSFH-17	KBSH-1
Days to 50% flowering	DCMS 42 x DSI 729	-13.33**	-10.34**	-5.45	-5.45
	CMS 7-1 x DSI 732	-11.30**	-10.53**	-7.27**	-7.27**
	DCMS 41 x DSI 743	-10.00**	-6.90*	-1.82	-1.82
	CMS 7-1 x DSI 695	-8.77**	-8.77**	-5.45	-5.45
Plant height	DCMS 41 x DSI 680	-28.96**	-28.52**	-37.80**	-45.24**
	DCMS 42 x DSI 695	-15.60**	-1.76	-30.86**	-39.12**
	CMS 7-1 x DSI 695	-13.51**	-10.99**	-22.39**	-30.79**
	CMS 7-1 x DSI 673	-13.49**	-12.14**	-22.41**	-31.68**
	DCMS 41 x DSI 695	-12.41**	-9.16	-20.96**	-30.41**
Stem diameter	CMS 335 x DSI 728	34.42**	24.26**	24.20**	30.90**
	CMS 335 x DSI 732	27.62**	24.33**	24.38**	31.09**
	DCMS 41 x DSI 732	21.16**	21.16**	14.96**	21.16**
	DCMS 41 x DSI 743	17.94**	17.72**	12.12**	18.16**
Head diameter	CMS 335 x DSI 743	59.75**	51.19**	-0.42	10.45**
	DCMS 41 x DSI 736	34.65**	15.00**	8.21	20.00**
	DCMS 41 x DSI 743	30.36**	5.92	-0.34	10.52**
	CMS 7-1 x DSI 728	26.03**	5.36	3.27	14.52**
	DCMS 42 x DSI 743	17.60**	-13.29**	7.42	19.13**
Days to maturity	DCMS 42 x DSI 729	-8.14**	-7.06**	-9.20**	-10.23**
	DCMS 42 x DSI 716	-7.34**	-5.88**	-8.05**	-9.09**
	DCMS 41 x DSI 716	-7.34**	-5.88**	-8.05**	-9.09**
	CMS 335 x DSI 725	-5.68**	-4.60**	-4.60**	-5.68**
Number of unfilled seed	DCMS 41 x DSI 724	-80.12**	-85.01**	-86.18**	-84.08**
	CMS 7-1 x DSI 680	-30.06**	-53.60**	-44.28**	-35.82**
	DCMS 42 x DSI 686	-21.90**	-45.61**	-40.91**	-31.94**
100-seed weight	DCMS 42 x DSI 724	44.11**	42.09**	42.09**	50.27**
	DCMS 41 x DSI 673	42.75**	30.36**	30.36**	37.86**
	DCMS 42 x DSI 743	40.77**	29.21**	54.59**	63.49**
	DCMS 41 x DSI 729	36.74**	34.76**	38.78**	46.76**
	CMS 7-1 x DSI 680	36.30**	1.20	28.83**	36.24**
Number of filled seeds/head	CMS 335 x DSI 732	77.99**	53.81**	80.69**	83.96*
	CMS 7-1 x DSI 743	58.59**	25.77**	78.80**	82.04**
	CMS 335 x DSI 729	50.19**	31.85**	49.25**	51.96*
	CMS 7-1 x DSI 724	44.42**	29.40**	83.95*	87.29*
	CMS 335 x DSI 725	42.60**	33.96**	30.41**	32.78**
Oil content	DCMS 42 x DSI 728	64.08**	48.00**	40.68**	-2.38
	DCMS 42 x DSI 724	63.79**	39.65**	51.33**	5.00
	DCMS 42 x DSI 732	36.00**	13.71**	29.28**	-10.30
Seed yield/plant	CMS 7-1 x DSI 743	111.46**	99.80**	49.49**	26.81**
	CMS 7-1 x DSI 724	99.10**	74.80**	53.94**	30.59**
	CMS 7-1 x DSI 716	78.44**	58.11**	36.31**	15.63**
Oil yield/plant	CMS 7-1 x DSI 743	111.14**	108.47**	94.86**	14.62**
	CMS 7-1 x DSI 724	82.94**	81.08**	72.78**	11.63**
	CMS 7-1 x DSI 716	65.75**	49.94**	73.19**	11.88**

The cross CMS 7-1 x DSI 743 recorded highest heterosis (111.46%) and heterobeltiosis (99.80%). Twelve hybrids over MSFH-17 and six hybrids over KBSH-1 have recorded significant positive standard heterosis for seed yield/plant. For oil yield/plant, 22 hybrids have recorded significant positive heterosis while 19 hybrids have recorded significant positive heterobeltiosis and 24 hybrids have recorded significant positive standard heterosis over MSFH-17. These results were in agreement with the results of Shivaraju (1984), Kadkol *et al.* (1984), Kandhola *et al.* (1995) and Gill and Sheoran (2002). From the above results it is clear that different hybrids exhibited different magnitude of heterotic effects for different characters no single cross exhibited significant heterosis for all the characters. A perusal of the data revealed that all the hybrids in which CMS 7-1 and DCMS 41 were involved as female parents have exhibited highest positive heterosis for plant height, head diameter, 100-seed weight, number of filled seeds/head, seed yield/plant and oil yield/plant. Further, among the testers, DSI 743, DSI 716 and DSI 724 were involved as male parents in most of the top hybrids with respect to heterosis, heterobeltiosis and standard heterosis. This indicated the presence of higher frequency of additive alleles in these two female and three male parents. Further, it gives an indication of good general combining ability of these lines for these characters. The crosses, CMS 7-1 x DSI 743, CMS 7-1 x DSI 724 and CMS 7-1 x DSI 716 were found superior to commercial check variety MSFH-17 in respect of both seed yield and oil yield. The main reason ascribed is diversified parents involved in the cross combination or uncommon genes for trait(s) which resulted in maximum exploitable levels of heterosis. 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 have wide scope and needs to be tested in large scale trails and also at different locations to confirm their superiority and stability across locations.

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Short communication

Comparison between path analysis studies in the biparental progenies and F_3 bulk population in the cross DCB 1799 x Gowri in sesame

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Studies on the importance of direct and indirect effects of component traits on seed yield in many crops are confined mostly to selfed populations. But, none of the studies compared these effects in the biparental progenies and selfed populations following hybridization. Joshi (1966) reported the effect of intermating in F_2 generation which resulted in the constellation of favourable genes and breaking of undesirable linkages which may result in improvement in the magnitude and direction of the direct and indirect effects. However, such studies enable the breeder to pin point a particular type of mating system to be used to improve a particular trait. Hence, the present study was taken under to compare the results of path analysis of biparental progiens with that of F_3 bulk population of the cross DCB 1799 x Gowri in Sesame .

Biparental progenies were generated in the F_2 generation of the cross DCB1799 X Gowri by adopting NCII mating model (Comstock and Robinson, 1952), in which 6 randomly selected females were crossed to 4 males and the resulting 24 biparental progenies along with corresponding F_3 bulk and parents were grown in randomized block design with two replications at Agricultural Research Station, Peddapuram during *kharif* 2002. Each BIP was represented by 2 rows of 4 m length spaced 30 cm apart. Healthy crop was raised as per recommended agronomic practices and data were recorded on 12 quantitative traits *viz.*, plant height, days to maturity, number of primary branches, capsules on main stem, capsules on primary branches, capsules/plant, capsule length, seeds/capsule, 1000 seed weight, biological yield, harvest index and seed yield/plant and subjected to path coefficient analysis as per Dewey and Lu (1959).

Comparison of the results on path analysis in the *Biparental progenies and F_3 bulk population (Table 1 and* 2) revealed that many of the negative direct effects of seeds/capsules, 1000 seed weight in F_3 bulk population turned out to be positive in the biparental progiens, which may be due to break down of undesirable linkages in F_3 to favourable linkages in Biparental progenies (Yunus and Paroda 1982). However, the direct effects of traits like number of primary branches and capsule length which showed positive direct effects in F_3 population turned to be negative in the Biparental progenies.

Table 1 Direct and indirect effects of path analysis in the biparental progenies of inferior cross (DCB 1799 x Gwori)

Character	Plant height	Days to maturity	No. of primary branches	Capsules on main stem	Capsules on primary branches	Capsules/ plant	Capsule length	Seeds/ capsule	1000 Seed weight	Biological yield	Harvest index
Plant height	-0.0141	-0.0059	-0.0064	-0.0082	-0.0089	-0.0102	-0.0069	-0.0058	-0.0002	-0.0097	0.0017
Days to maturity	-0.0097	-0.0233	-0.0081	-0.0079	-0.0110	-0.0127	-0.0098	-0.0040	0.0020	-0.0094	0.0024
No .of primary branches	-0.0014	-0.0011	-0.0032	-0.0007	-0.0017	-0.0020	-0.0015	0.0006	-0.0011	-0.0016	0.0006
Capsules on main stem	0.0423	0.0247	0.0158	0.0724	0.0223	0.0502	0.0434	0.0258	0.0268	0.0321	0.0220
Cap. on primary branch	0.0093	0.0070	0.0079	0.0046	0.0148	0.0115	0.0065	0.0031	0.0038	0.0128	-0.0015
Capsules/plant	0.1225	0.0926	0.1077	0.1179	0.1324	0.1699	0.1025	0.0286	0.0604	0.1390	-0.0133
Capsule length	-0.0130	-0.0112	-0.0129	-0.0160	-0.0117	-00161	-0.0266	-0.0028	-0.0091	-0.0106	-0.0059
Seeds/capsule	0.0218	0.0091	-0.0092	0.0189	0.0110	0.0089	0.0056	0.0531	0.0038	0.0914	0.0112
1000 Seed weight	0.0002	-0.0010	0.0042	0.0044	0.0030	0.0042	0.0040	0.009	0.0118	0.0023	0.0017
Biological yield	0.5545	0.3256	0.4887	0.3584	0.7011	0.6613	0.3052	0.2949	0.1591	0.8086	-0.2113
Harvest index	0.0497	-0.0437	-0.0719	0.1267	-0.0416	-0.0327	0.0923	0.0878	0.0593	-0.1091	0.4176
Correlation with seed yield per plant	0.7619**	0.3726**	0.4327**	0.6704**	0.8097**	0.8325**	0.5147**	0.4820**	0.3166**	0.8743**	0.2217

Residual effect : 0.062; Direct effects - Diagonal; Indirect effects = Non-diagonal *, ** Significant at 5% and 1% level, respectively

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Table 2 Direct and indirect effects of path coefficient analysis in F_3 bulk population of inferior cross (DCB 1799 x Gowri)

Character	Plant height	Days to maturity	No. of primary branches	Capsules on main stem	Capsules on primary branches	Capsules/ plant	Capsule length	Seeds/ capsule	1000 Seed wight	Biological yield	Harvest index	Correlation with seed yield per plant
Plant height	0.023	-0.003	0.000	-0.008	-0.017	0.024	0.002	0.000	-0.004	0.378	0.044	0.440**
Days to maturity	0.003	-0.025	0.000	0.186	-0.101	-0.282	0.000	0.003	0.001	0.133	-0.059	0.062
No.of primary branches	0.000	0.000	0.006	0.06	0.123	-0.183	-0.001	-0.001	0.002	0.089	0.091	0.186
Capsules on main stem	0.000	-0.009	0.001	0.537	0.114	-0.634	-0.001	0.005	0.000	0.353	-0.167	0.198
Capsules on primary branches	-0.001	-0.008	0.002	0.191	0.32	-0.508	0.002	0.001	-0.002	0222	0.024	0.244
Capsules per plant	-0.001	-0.01	0.001	0.485	0.231	-0.702	0.000	0.004	-0.001	0.363	-0.112	0.259*
Capsule length	0.003	0.000	0.000	-0.048	0.042	0.004	0.016	-0.004	-0.003	0.041	-0.029	0.021
Seeds per capsule	0.000	0.007	0.001	-0.191	-0.019	0.203	0.005	-0.013	0.001	-0.04	0.060	0.014
1000 Seed weight	0.005	0.001	0.000	0.000	0.024	-0.024	0.003	0.001	-0.021	0.055	0.026	0.068
Biological yield	0.009	-0.003	0.000	0.187	0.07	-0.251	0.001	0.001	-0.001	1.016	-0.255	0.773
Harvest index	0.002	0.002	0.001	-0.132	0.011	0.116	-0.001	-0.001	-0.001	-0.382	0.679	0.293*

Residual effect : 0.0648; *Significant at 5% level; ** Significant at 1% level; Direct effects - Diagonal; Indirect effects = Non-diagonal

The indirect effects revealed an increase in magnitude and direction in respect of the traits *viz.*, capsules on primary branches, capsules on main stem, biological yield and height of the plant in the biparental progenies compared to *their corresponding F_3 bulk population, which serves an* example of impact of intermating in F_2 population (Sudharani *et al.*, 1996). The traits capsules on main stem and capsules on primary branches can be phenotypically identified easily in the selection programme and hence, selection criteria can be framed based on these traits.

The increase in magnitude of direct effects of biological yield and harvest index in the biparental progiens compared to F_3 bulk populations could be due the fact that coupling phase linkages might have broken down during intermating in F_2 .

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Short communication

Variability studies in linseed, *Linum usitatissimum* L.

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In India, linseed, *Linum usitatissimum* L is grown as a winter crop mostly in sub-marginal lands under un-irrigated and 'Utera' conditions. Chhattisgarh is one of the important linseed growing states of India, which accounts nearly 19.05% area and 16.21% production of country. In Chhattisgarh linseed is having 132.2 thousand ha. area with a productivity of 260 kg/ ha (Anonymous, 2001). Advance in the development of crop varieties and hybrids greatly depend upon the diverse source of material. Genetic variability is one of the pre-requisites for any crop improvement so the study of genetic variability with the help of suitable parameter such as genetic coefficient of variation, heritability and genetic advance are absolutely necessary to start an efficient breeding programme.

The present investigation was conducted at Research Farm, I.G.A.U., Raipur during rabi 2000-01.The experimental material comprised of 21 cross combinations derived from 13 parents of linseed. In which parent P_1, P_2 and F_2, F_3 generations were grown in Randomized Complete Block Design with three replications. In each plot, one row each of P_1 and P_2, and 6 rows each of F_2 and F_3 were randomly allotted. The sowing was done on December 2, 2001. The observations were recorded on randomly selected plants, in each row i.e. five from P_1, five from P_2, 30 each from F_2 and F_3 in each plot and also from each replication for 10 characters (Table 1).

Table 1 Genetic parameters of variation for yield and its components of linseed

Character	Phenotypic coefficient of variation	Genotypic coefficient of variation	Heritability (broad sense)	Genetic advance (GA)	GA as % of mean
Days to 50% flowering	4.34	3.58	0.681	3.34	6.08
Days to maturity	2.54	2.05	0.653	3.28	3.28
Plant height (cm)	13.74	12.50	0.827	12.37	23.41
Number of primary branches/ plant	28.81	21.32	0.547	0.82	32.54
Number of secondary branches/ plant	27.38	25.53	0.869	3.76	49.02
Number of capsules/plant	29.09	28.46	0.957	10.40	57.39
Number of seeds/ capsule	17.64	17.51	0.936	1.93	35.80
Number of seeds/ plant	40.73	40.69	0.998	83.75	83.75
100 seed weight (g)	21.75	18.81	0.743	0.29	33.33
Seed yield (g)	32.39	30.09	0.863	0.50	58.13

The existence of high magnitude of genetic variability observed for all the character under study revealed by high genetic coefficient of variation. The genotypic variance was smaller than phenotypic variance, it showed that environment, did exert masking influence on the expression of genetic variability. Comparison of relative magnitude of genotypic coefficient of variation for parental population revealed that maximum amount of genetic variability was present for number of seeds/plant. High amount of genotypic coefficient of variation was possessed by number of primary branches/plant, number of secondary branches/plant, number of capsules/plant and seed yield/plant (g). The moderate genotypic coefficient of variation was recorded for plant height , number of seeds/capsule and 100 seed weight . Low genotypic coefficient of variation was recorded for days to 50% flowering and days to maturity (Table 1). Earlier findings of Bhateria *et al.* (2001), Varshney *et al.* (1995), Gupta *et al.* (1999), Mishra and Yadav (1999) and Verma (1999) were in agreement with present study. Heritability and genetic advance are important selection parameters. Heritability estimates along with genetic advance are normally more helpful in predicting the grain under selection than heritability estimates alone. High heritability coupled with high genetic advance was observed for number of seeds/plant (99.8%, 83.7%), number of capsules/plant (95.7%, 57.3%), number of seeds/capsule (93.6%, 35.8%), number of secondary branches/plant (86.9%, 49.0%) and

100 seed weight (74.3%, 33.3%). The major character, seed yield/plant (g) possesses high heritability with high genetic advance (86.3%, 58.1%), indicating prevalence of fixable type of genetic variation for the expression of these traits. These results fall in line with those of Mirza *et al.* (1996) and Mishra and Yadav (1999).

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Short communication

Genetic variability and path analysis for seed yield in linseed, *Linum usitatissimum* L.

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Linseed (*Linum usitatissimum* L.) is an important *rabi* oilseed crop of Chhattisgarh. The irrigated area in the state is very low. In Chhattisgarh linseed is grown mostly *rainfed as 'Utera' as well as in open fields. Hence linseed* plays an important role in the double cropped area. Improvement of genetic architecture of any crop depends upon the nature and extent of genetic variability required to effect selection in any breeding material. Yield is a complex character and can not be improved by direct selection as it is influenced by a number of independent characters. Thus association of various characters the yield and among themselves would provide criteria for indirect selection through components for improvement of yield. Therefore, the study was undertaken to find out the extent of variability, heritability, genetic advance, correlation and path analysis for various traits in linseed.

The experimental material consisting of 20 genotypes derived from 22 diverse parents along with 6 checks were grown during *rabi* 2002-03 in sets of environments *viz.*, rainfed, irrigated and *utera* Each set of experiment was laid out in Randomized Complete Block Design with three replications at oilseed research area of Research Farm, IGAU, Raipur. Each genotype was grown in the plot consist of 4 rows of 4 m. length with 30 cm apart between the rows. Sowing was done through broadcasting in case of *utera environment. Data were collected on plot basis* for days to flower, days to maturity and five randomly selected plants in each genotype of every replication basis for plant height, number of primary branches/plant, number of secondary branches/plant, number of capsules/plant, number of seeds/capsule, 1000 seed weight and seed yield/plant for all the three environments. Genetic parameters of variation, correlations and path analysis are carried out based on pooled data/ pooled mean of three environments. Pooled analysis of variance was done following the procedure given by Gomez and Gomez (1984) and Khorgade (1992). Estimation of genetic parameters by Johnson *et al.* (1955) and Allard (1960). Phenotypic and genotypic correlations were worked out according to Al-Jibouri *et al.* (1958) and path analysis as *per Dewey and Lu, 1959.*

The analysis of variance revealed highly significant differences among the genotypes for nine characters studied, except number of secondary branches and *capsules/plant under irrigated environment. The range of* variation was maximum for plant height, primary and secondary branches/plant, number of capsules/plant, 1000 seed weight and seed yield/plant. It indicates that there is *better scope for selection and improvement of these* characters and also was supported by phenotypic and genotypic coefficients of variability. Johnson *et al.* (1955) reported that heritability and genetic advance as percentage over mean together were more useful for predicting the result and effect of selected genotypes than heritability or genetic advance as percentage over mean alone (Table 1). High heritability in broad sense was recorded for all the characters except number of primary and secondary branches/plant, number of capsules/plant, number of seeds/capsule which showed moderate heritability estimates. High heritability estimates coupled with high genetic advance as observed in days to flower, 1000 seed weight and seed yield/plant revealed pre dominance of additive gene action for these characters and thus ensured reliability for direct selection. Similar findings were also reported by earlier workers, Malik and Singh (1995), Varshney *et al.* (1995), Singh *et al.* (1995), Mirza *et al.* (1996).

In general the genotypic correlation coefficients were higher than the phenotypic indicting masking effect of the environment (Table 2). Seed yield had significant positive association with number of secondary branches/plant and number of capsules/plant. Only days to flower had showed negative significant association with 1000 seed weight. Path coefficients are given in Table 3. Number of capsules/plant and 1000 seed weight exhibited positive direct effect on seed yield. The association of these characters with seed yield was also positive and significant indicating the importance of these traits for improving seed yield. The results are in agreement with the earlier findings of Naik and Satpathy (2002). Days to maturity, number of primary and secondary branches/plant recorded significant negative direct effects on seed yield. Days to flower and plant height recorded low direct effect on seed yield

revealed low priority in selection for high seed yield. These results were corroborate with Khorgade (1992), Mirza *et al.* (1996), Chandrasekar *et al.* (1998) and Naik and Satapathy (2002).

In the present study, number of secondary branches/plant, *capsules/plant and 1000 seed weight having high* heritability and moderate to high genetic advance, positive correlation with high direct effects could be considered as selection criteria for improving seed yield in linseed.

Table 1 Parameters of variability for yield and its components in linseed

Character/ genetic parameter	Mean ± *SEm*	Range *Min. - Max.*	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability broad sense (%)	Genetic *advance*	Genetic advance as % of mean
Days to flower	49.91±0.41	40.40-62.72	9.80	9.96	96.9	9.92	24.55
Days to maturity	107.55±0.50	103.47-111.98	2.31	2.51	84.5	4.70	4.54
Plant height (cm)	47.45±1.09	38.23-55.99	7.67	9.10	71.0	6.32	16.53
No. of primary branches/plant	3.73±0.22	2.91-5.57	10.12	16.11	39.5	0.49	16.84
No. of secondary branches/plant	9.45±0.54	6.14-12.11	12.91	17.66	53.5	1.84	29.97
No. of capsules/plant	38.63±1.85	29.40-48.66	13.16	16.64	62.6	8.28	28.16
No. of seeds/capsule	7.59±0.29	6.34-8.64	5.97	9.80	37.1	0.57	8.99
1000-seed weight (g)	6.38±0.09	4.48-7.98	12.60	12.95	94.8	2.61	58.26
Seed yield/plant (g)	1.93±0.11	1.23-3.42	22.51	25.99	76.3	0.78	63.41

Table 2 Phenotypic (r_p) and genotypic (r_g) correlation coefficients among yield and yield components in linseed

Character		*Days to* maturity	Plant height (cm)	Number of primary branches/plant	Number of secondary branches/plant	Number of capsules/ plant	Number of seed/capsule	1000 seed weight (g)	*Seed* yield/plant (g)
Days to flower	r_p	0.186	0.312	-0.143	-0.065	-0.069	0.296	-0.415*	-0.123
	r_g	0.208	0.373	-0.246	-0.088	-0.087	0.448*	-0.438	-0.138
Days to maturity	r_p		0.178	-0.093	0.001	0.141	0.187	0.272	-0.008
	r_g		0.191	-0.142	0.055	0.224	0.343	0.308	0.009
Plant height (cm)	r_p			*-0.259*	*-0.169*	-0.069	0.150	-0.143	-0.073
	r_g			-0.575	-0.350	-0.183	0.211	-0.176	-0.072
Number of primary branches/ plant	r_p				0.368	0.173	-0.052	0.100	0.066
	r_g				0.441*	0.065	-0.137	0.127	0.043
Number of secondary branches/ plant	r_p					0.616**	-0.033	0.039	0.436*
	r_g					0.717**	-0.129	0.079	0.486*
Number of capsules/ plant	r_p						0.039	0.080	0.675**
	r_g						-0.014	0.093	0.774**
Number of seed/ *capsule*	r_p							-0.300	0.052
	r_g							*-0.446**	*0.035*
1000 seed weight (g)	r_p								0.313
	r_g								0.361

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

Table 3 **Phenotypic (P) and genotypic (G) path coefficients for yield and its components in linseed**

Character		Days to flower	Days to maturity	Plant height	Number of primary branches/plant	Number of secondary branches/plant	Number of capsules/ plant	Number of seed/ capsule	1000 seed weight (g)	Correlation with Seed yield/plant (g)
Days to flower	P	**0.087**	-0.053	0.004	0.016	-0.003	-0.046	0.053	-0.181	-0.123
	G	**0.132**	-0.132	0.081	-0.018	0.014	-0.088	0.199	-0.326	-0.138
Days to maturity	P	0.016	**-0.283**	0.002	0.011	0.001	0.094	0.033	0.119	-0.008
	G	0.027	**-0.635**	0.042	-0.011	-0.009	0.026	0.140	0.229	0.009
Plant height	P	0.027	-0.050	**0.011**	0.029	-0.009	-0.046	0.027	-0.063	-0.073
	G	0.049	-0.121	**0.218**	-0.043	0.054	-0.185	0.086	-0.131	-0.072
Number of primary branches/ plant	P	-0.013	0.026	-0.003	**-0.113**	0.019	0.115	-0.009	0.044	0.066
	G	-0.032	0.090	-0.125	**0.075**	-0.068	0.066	-0.056	0.094	0.043
Number of secondary branches/ plant	P	-0.006	0.001	-0.002	-0.042	***0.050***	*0410*	*-0.006*	*0.030*	0.436*
	G	-0.012	-0.035	-0.076	0.033	**-0.155**	0.724	-0.053	0.059	0.486*
Number of capsules/ plant	P	-0.006	-0.040	-0.001	-0.020	0.031	**0.668**	0.007	0.035	0.675**
	G	-0.011	-0.142	-0.040	*0.005*	-0.111	**1.010**	-0.006	0.069	0.774**
Number of seed/ capsule	P	0.026	-0.053	0.002	0.006	-0.002	0.026	**0.178**	-0.131	0.052
	G	0.064	-0.218	0.046	-0.010	0.020	-0.014	**0.408**	-0.331	0.035
1000 seed weight (g)	P	-0.036	-0.077	-0.002	-0.011	0.003	0.053	-0.053	**0.436**	0.313
	G	-0.028	-0.193	-0.038	0.009	-0.012	0.094	-0.182	**0.743**	0.361

*, ** Significant at 5% & 1% levels, respectively; *Diagonal : Direct effects (bold)* ; *Non diagonal : Indirect effects*
Genotypic residual effect : 0.0768; Phenotypic residual effects : 0.3980

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Short communication

Differential susceptibility of *brassica* genotypes to sulphur stress conditions

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Role of sulphur in crop production particularly in oilseeds and pulses is well known in higher plants, patterns of gene expression and metabolic activities are modified upon exposure to sulphur deficiency. Of late, sulphur deficiency has been aggravated in Indian soils. Singh (2004) reported that about 23% soils of Yamuna river basin of Haryana state are deficient in available S. In light textured soils, sulphur deficiency has been reported at an alarming frequency for cereals, pulses, oilseed and bulb crops (Tiwari,1995). In countries such as India, vitally concerned with increasing food production, sulphur is one element that must not be overlooked (Kanwar,1997) Limited information is available about the differences in effect of sulphur on the yield and accumulation of sulphur among Brassica genotypes. Hence, the present study was undertaken to investigate the effect of sulphur on yield, concentration and uptake of sulphur in seed and stover among *Brassica* genotypes.

A screen house experiment was conducted on fine loamy non calcareous deep mixed hypothermic Typic Ustochrepts soils having pH 8.20, EC 0.15 dS/m, CEC 7.50 cmol (p^+)/kg, OC 15 g/kg, $CaCO_3$ traces and 0.15% $CaCl_2$ extractable S 7.5 mg/kg soil. The 5 kg air-dried soil sieved through 2 mm sieve was filled in polythene lined earthern pots. A basal dose of NPK and Zn was applied @ of 100, 50, 62.5 and 5 mg/kg through urea, KH_2PO_4 and $ZnCl_2$, respectively. Sulphur was applied @ 0.20 and 40 mg/kg soil through ammonium sulphate. Deionized water was used for irrigation and each treatment was replicated thrice. Ten seeds of eight genotypes of Brassica *viz.*, Varuna, Vardan, DHR-9504, Rajat, Vaibhav, RH-30 Subinoy and Jhumka were sown in each pot. After germination and thinning, four plants were allowed to grow in each pot up to maturity. Dry matter yield of grain and stover were recorded for each genotype. Plant samples were digested in 4:1 diacid mixture of HNO_3 and $HClO_4$ and S was determined by turbidimetric method.

There was considerable variation among the eight genotypes in the magnitude of yield response in seed and stover under S stress condition. Seed yield of all *Brassica* (Indian mustard) genotypes, increased significantly at 20 mg/kg level over control (Table 1). A decrease in response was noted at 40 mg S/kg application. Hence, 20 mg S/kg soil was sufficient for optimum growth of *Brassica* spp, Among the genotypes, the seed yield of RH-30, Subinoy and Jhumka were about half of Varuna under S stress condition. Grain yield differences among genotypes under no S treatment and those at 20 mg/kg S application were almost at par. Yield variability under S stress could be due to differences in S susceptibility and differences in production potential. The interaction between S levels and genotypes was also significant. The highest seed yield response was recorded in Jhumka and least in Vaibhav.

All the tested genotypes resulted in a significant stover yield response at 20 mg S/kg whereas at 40 mg S/kg level a significant reduction was observed. The maximum stover yield response was found in Vaibhav and minimum in DHR-9504. Different genotypes differed significantly with respect to the seed and stover yield and the interaction between S levels and genotypes was also found significant. Kumar *et al.*(2001) reported that on sulphur application Varuna cultivar of Indian mustard gave significantly higher seed and stover yields than Vardan.

In seed and stover, S concentration increased significantly with the increasing level of S application over control in all the genotypes. The S concentration at zero S level in seed and stover ranged from 0.78 to 1.17% and 0.39 to 0.62% respectively, in different genotypes. Thus, there was a considerable variability between genotypes in their capacity to exploit soil S. In seed, the highest S concentration was found in DHR-9504 and lowest in Vardan whereas in stover it was maximum in Jhumka and minimum in Rajat and RH-30. The high S concentration in seed at zero S level compared to stover showed that a large proportion of S was translocated to seed. Kala and Gupta (1996) while studying comparative response of some *rabi* crops to sulphur application also reported highest sulphur concentration in *raya* seed. The interaction between S levels and genotypes was also found significant in both seed and stover S concentrations.

Sulphur accumulation in plants is a function of S concentration and dry matter weight. Amounts of S taken up by the stover of the *Brassica* genotypes had increased significantly with increasing S levels and it was two to three times relatively more as compared to seed. Significant differences among genotypes and S levels were noted in S accumulation in seed and stover. Seed S

uptake was highest in Varuna and lowest in Subinoy and the corresponding genotypes for stover S uptake were DHR-9504 and RH-30, respectively. The amount of S accumulation in stover and translocation to seed of *Brassica* plants varied with genotypes. The interaction between genotypes and S levels were also significant in both seed and stover. The variability in the S uptake among different genotypes decreased after S application.

Brassica genotypes differ in their response to sulphur stress condition. Much of genotypic variability under S stress in yield is both due to differences in S susceptibility and differences in their production potential. Genotypes Jhumka and RH-30 were most susceptible whereas DHR-9504 and Vaibhav were least susceptible to sulphur stress condition.

Table 1. Yield, S-concentration and S-uptake of *Brassica* genotypes as influenced by sulphur application

S levels (mg/kg)	Genotypes								Mean
	Varuna	Vardan	DHR-9504	Rajat	Vaibhav	RH-30	Subinoy	Jhumka	
Seed yield (g/pot)									
0	7.3	4.8	5.2	6.0	4.3	3.7	3.4	3.8	4.8
20	10.1	7.7	7.7	8.7	5.1	6.1	5.3	6.7	7.2
40	8.7	6.9	7.5	7.8	4.9	5.3	4.7	5.4	6.4
Mean	8.7	6.5	6.8	7.5	4.8	5.0	4.4	5.3	---
CD(P=0.05)	S levels= 0.11			Genotypes= 0.18			S x G= 0.32		
Stover yield (g/pot)									
0	26.2	25.6	28.2	27.2	23.7	17.0	17.9	16.3	22.9
20	30.8	30.8	30.4	31.2	24.8	21.8	22.7	20.7	26.7
40	28.2	28.8	30.0	28.7	24.0	18.8	21.5	19.0	24.9
Mean	28.4	28.7	29.5	29.0	24.2	19.2	20.7	18.7	-----
CD(P=0.05)	S levels= 0.28			Genotypes= 0.45			S x G= 0.79		
S-concentration in seed (%)									
0	0.93	0.78	1.17	1.01	1.00	1.05	0.94	1.08	0.99
20	1.01	0.86	1.23	1.11	1.05	1.09	1.11	1.14	1.08
40	1.09	0.93	1.35	1.17	1.13	1.12	1.22	1.21	1.15
Mean	1.01	0.86	1.26	1.10	1.06	1.09	1.09	1.14	----
CD(P=0.05)	S levels= 0.01			Genotypes= 0.02			S x G= 0.03		
S-concentration in stover (%)									
0	0.45	0.39	0.46	0.40	0.41	0.49	0.56	0.62	0.47
20	0.76	0.75	0.81	0.68	0.83	0.63	0.70	0.85	0.75
40	0.84	0.81	0.87	0.79	0.93	0.75	0.85	0.94	0.85
Mean	0.68	0.65	0.71	0.62	0.73	0.62	0.71	0.80	----
CD(P=0.05)	S levels= 0.01			Genotypes= 0.02			S x G= 0.04		
S-uptake in seed (mg/pot)									
0	6.79	3.76	6.12	6.09	4.30	3.86	3.16	4.06	4.77
20	10.17	6.64	9.75	9.66	5.37	6.66	5.83	7.65	7.72
40	9.52	6.42	10.15	9.19	5.59	5.88	5.68	6.47	7.36
Mean	8.83	5.61	8.67	8.31	5.09	5.47	4.89	6.06	-----
CD(P=0.05)	S levels = 0.10			Genotypes = 0.16			S x G = 0.27		
S-uptake in stover (mg/pot)									
0	11.69	10.44	12.90	10.80	9.79	8.26	10.07	10.03	10.50
20	23.43	23.22	24.63	21.24	20.66	13.71	16.06	17.55	20.06
40	23.64	23.61	26.21	22.67	22.40	14.13	18.29	18.39	21.17
Mean	19.59	19.09	21.24	18.24	17.62	12.04	14.81	15.32	----
CD(P=0.05)	S levels = 0.26			Genotypes = 0.43			S x G = 0.75		

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Short communication

Nutrient management in sunflower-pigeonpea intercropping system in vertisols

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Currently with intensive farming involving promising hybrids and varieties, demand for chemical fertilizers has been increased. Due to energy crisis, prohibitive costs of fertilizers and low purchasing power of marginal and small farmers it is very difficult to meet the demand of plant nutrients through chemicals, fertilizers alone (Hegde, 1998). It is also felt that there is degradation of soil physical and chemical properties with continuous use of chemical fertilizers and intensive cultivation, hence, a major source of nutrients has to necessarily come from locally available organic sources like FYM, vemicompost, poultry manure, etc. No such studies were carried out on intercrops under rainfed conditions. Hence, the present investigation was aimed at studying the effect of organic sources and inorganic fertilizer levels on seed yield, stalk yield and harvest index of sunflower and pigeonpea intercropping system grown on a vertisol.

A field experiment was conducted at Main Research Station, University of Agricultural Sciences, Dharwad on vertisol with pH 7.7; EC 0.28 dS/m, organic carbon 0.61%, available N 150 kg/ha, P_2O_5 32 kg/ha and K_2O 313 kg/ha under rainfed conditions during *kharif*, 1998. The experiment had 15 treatment combinations comprising three organic sources (FYM, vermicompost and poultry manure) and five inorganic fertilizer levels to pigeonpea (100, 75, 50, 25 and 0% RDF) and 100% RDF to sunflower kept same for all the treatments. The experiment was laid out in a Factorial Randomised Block Design with three replications, on an average FYM contained (0.49% N, 0.65% P_2O_5 and 0.57% K_2O), vermicompost contained (0.78% N, 0.94% P_2O_5 and 0.45% K_2O) and poultry manure contained (.144% M, 1.97% P_2O_5 and 0.32% K_2O). The organic sources were applied as per treatments a fortnight prior to sowing. The inorganic fertilizers were drilled in the soil as per treatment combinations. Fertilizer was applied at 5 cm away from seed line to a depth of 5 cm. Two to three seeds of sunflower (KBSH-1) and pigeonpea (S-1) were dibbled 4-5 cms deep at 30 cms intervals in rows spaced at 60 cm apart in both crops with 2:1 row proportions.

Sunflower yield: Application of different organic sources along with 100% RDF to sunflower and different RDF levels to pigeonpea had no significant influence on the seed yield, stalk yield and harvest index of sunflower (Table 1). However, the highest seed yield (14.25 q/ha) of sunflower was recorded under vermicompost + 100% RDF to both sunflower and pigeonpea than the rest of the treatments.

Sunflower did not responded significantly with application of different organic sources along with 100% RDF to sunflower and different RDF levels to pigeonpea (Table 1).

Pigeonpea yield: Application of different organic sources like FYM, vermicompost or poultry manure along with 100% RDF to both sunflower and pigeonpea significantly improved the seed yield (8.80 q/ha) of pigeonpea as compared to application of either FYM, vermicompost or poultry manure along with 100% RDF to sunflower and no fertilizer to pigeonpea 7.38 q/ha). Application of either FYM, vermicompost or poultry manure in conjunction with 100% RDF for both sunflower and pigeonpea crops increased pigeonpea seed yield by 17.04% over application of either FYM< vermicompost or poultry manure in conjunction with 100% RDF for only sunflower and no RDF to pigeonpea. The beneficial effect of organic sources along with inorganic fertilizer levels could be due to more available plant nutrients to plants and also have solubilising effect on fixed forms of nutrients in soil (Ganai and Singh, 1998).

Pigeonpea also did not respond significantly with different organic sources with 100% RDF to sunflower and different RDF levels to pigeonpea with respect to seed yield and harvest index of pigeonpea (Table 1).

Sunflower equivalent yield: Among the organic sources, application of vermicompost @ 4.7 t/ha recorded significantly higher sunflower seed equivalent yield (22.54 q/ha) than with FYM (20.84 q/ha) and it was on par with that recorded under poultry manure (22.08 q/ha).

Application of 100% RDF to both sunflower and pigeonpea recorded significantly higher sunflower seed equivalent yield (23.39 q/ha) than that recorded under 100% RDF to only sunflower and no fertilizer to pigeonpea (19.69 q/ha). Similar results were recorded by Kulmi (1996).

Sunflower seed equivalent yield was not influenced significantly by organic sources with 100% RDF to

sunflower and different RDF levels to pigeonpea. However, higher sunflower seed equivalent yield was recorded (24.16 q/ha) under vermicompost in conjunction with 100% RDF to both sunflower and pigeonpea.

In sunflower pigeonpea intercropping system about 25 to 50% fertilizers can be saved. Among the organics poultry manure was found superior followed by vermicompost and FYM, respectively.

Table 1, Seed yield of sunflower, pigeonpea and sunflower seed equivalent yield (q/ha)

Organics (Sunflower+Pigeonpea)	Sunflower Seed yield (q/ha)				Pigeonpea Seed yield (q/ha)				Sunflower seed equivalent yield (q/ha)			
	FYM	Vermi-compost	Poultry manure	Mean	FYM	Vermi-compost	Poultry manure	Mean	FYM	Vermi-compost	Poultry manure	Mean
100% RDF + 100% RDF	12.4	14.2	13.8	13.4	8.6	8.8	8.9	8.8	22.1	24.1	23.9	23.3
100% RDF + 75% RDF	12.1	14.1	13.5	13.2	8.3	8.6	8.3	8.4	21.5	23.9	22.9	22.7
100% RDF + 50% RDF	11.7	13.8	12.5	12.7	8.0	8.5	8.5	8.3	20.7	23.4	22.1	22.1
100% RDF + 25% RDF	11.6	12.4	11.9	12.0	7.8	7.8	8.4	8.0	20.5	21.3	21.4	21.1
100% RDF + No RDF	11.1	11.4	11.5	11.3	7.2	7.4	7.4	7.3	19.2	19.8	19.9	19.6
Mean	11.8	13.2	12.6	12.5	8.1	8.2	8.3	8.2	20.8	22.5	22.0	21.8
For comparing means of												
Source	Org.	Inorg.	Org. X Inorg.		Org.	Inorg.	Org. X Inorg.		Org.	Inorg.	Org. X Inorg.	
SEm±	0.43	0.55	0.95		0.19	0.24	0.42		0.46	0.59	1.03	
CD (P=0.05)	NS	NS	NS		NS	0.70	NS		1.33	1.72	NS	

RDF = Recommended dose of fertilizer

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Short communication

Studies on planting geometry of male parent (R-64NB) on pollen production and its influence on seed yield in sunflower hybrid seed production (RSFH-1)

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Sunflower (*Helianthus annuus* L.) is one of the important members of Asteraceae family and the second most important edible oilseed crop of the world next to soybean. Presently in India, sunflower is grown over an area of 2.01 m.ha with a production of about 1.09 m. tonnes and productivity of 539 kg/ha. In Karnataka, sunflower is grown over an area of 0.88 m.ha with annual production of 0.41 m. tonnes and production of 463 kg/ha (Anonymous, 2004).

The crop has been well accepted by farming community because of its desired attributes such as short duration, photoperiod insensitivity, low seed rate, high seed multiplication ratio, drought tolerance, high quality edible oil and high degree of poly unsaturated fatty acid content. Due to intensive crop improvement programme, quite a number of hybrids have been released both at State and National level which demands the development of seed production technology. At present, majority of sunflower hybrids have branching type of restorer lines. These lines are characterized by high *per se* oil content, disease resistance and ensured pollen supply over longer duration in hybrid seed production due to contribution by secondary heads. In contrast, the non-branching restorers being mono head posses high test weight and *per se* oil content, but the pollen supply is restricted to shorter duration in seed production.

The seed production is influenced by several factors among which the most important single factor which determines the hybrid seed production is adequate pollen supply by restorer line. Since the restorer line (R64-NB) of RSFH-1 is monoheaded the only alternative way to increase pollen production is to increase the plant population of restorer line within the recommended planting proportion of 3:1 female to male lines, respectively. Keeping these in view, the present investigation was undertaken.

The field experiment was conducted at Main Agricultural Research Station, College of Agriculture, Dharwad during *rabi* season of 2004. The experiment was laid out in Randomized Block Design with four replications, consisting of treatments *viz.*, T_0-60x30 cm single row (55,555 plants/ha), T_1-60x30 cm paired row (1,11,110 plants/ha), T_2-60x20 cm single row (83,333 plants/ha), T_3-60x20 cm paired row (1,66,666 plants/ha), T_4-45x30 cm single row (74,074 plants/ha) and T_5-45x30 cm paired row (1,48,148 plants/ha). The seeds of pollen parent (R-64NB) were dibbled at an inter and intra row spacing as per treatments. The recommended dose of fertilizer 60:90:60 kg $N:P_2O:K_2O$/ha was applied. The seed crop was raised on black cotton soil and three irrigations were given at critical stages. The data on plant height, capitulum diameter, days to 50% flowering and pollen production were recorded. Five randomly selected restorer plant heads were covered with cloth bags before opening of flower. After the opening of disc florets the pollen produced was collected daily and weighed separately and pollen production/ha was worked out. The observations on number of filled seeds, unfilled seeds, seed set percentage, test weight, seed yield/plant, seed yield/ha and oil content were recorded from seed parent (CMS-103A).

Significantly higher plant height was recorded in restorer planted at 60x20 cm paired row may be due to more inter plant competition which activated the meristematic activity of cells resulting in increased plant height. Earlier, Kumar and Mohammad (2001) also reported an increase in plant height in sunflower due to increase in plant population. The days to 50% flowering did not differ significantly at all the spacings (Table 1).

Significantly more capitulum diameter was recorded with 60x30 cm single row and lowest (11.93 cm) in 60x20 cm paired row. Similar results were also reported by Ortegon and Diaz (1997) and Kumar and Mohammad (2001) in sunflower.

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The pollen production in male was distributed over 12 days during the flowering period (Table 2). The pollen production reached its maximum level on 4th and 5th day and thereafter it declined. Similar findings were also reported by Easwar (1996). Total pollen production/plant decreased with increasing in plant population. In case of lower plant density significantly more pollen production (712.75 mg) was recorded. This might be attributed to larger head size (14.5 cm) owing to less interplant competition for light, nutrients and moisture. The increased head size provides sufficient space for the development of individual disc floret leading to more pollen production (Kannababu *et al.*, 1993). The results of the present study are in conformity with the findings of Vermeulen (1985), Easwar (1996) in sunflower who observed that wider spacing provided more pollen producing surface.

The mean daily pollen production/plant decreased with the increase in plant population may be due to more amount of total pollen production/plant on account of bigger size capitulum noticed with plant recorded in lower plant population. The total pollen production is a function of size of capitulum and number of plants/unit area. In the present study the total pollen production/ha increased with increase in plant population (Table 2).

Table 1 Effect of planting geometry on growth, pollen production in restorer (R-64NB) and its influence on seed yield components in female parent (CMS-103A) of sunflower hybrid RSFH-1

Treatment	Plant height (cm)	Days to 50% flowering	Capitulum diameter (cm)	Pollen production (kg/ha)	No. of filled seeds	Test weight (g)	Seed set (%)	Seed yield (g/plant)	Seed yield (kg/ha)	Processed seed yield (kg/ha)	Oil content (%)
T_0-60x30 cm single row (55,555 plants/ha)	116	72	14.3	39.6	413	4.2	66.8	17.2	700	616	40.7
T_1-60x30 cm paired row (1,11,110 plants/ha)	128	73	12.5	67.9	451	4.1	71.0	18.7	758	656	40.2
T_2-60x20 cm single row (83,333 plants/ha)	126	72	12.9	52.8	424	4.2	69.4	17.6	721	626	40.6
T_3-60x20 cm paired row (1,66,666 plants/ha)	135	74	11.9	95.2	480	4.1	73.4	19.6	809	687	39.4
T_4-45x30 cm single row (74,074 plants/ha)	122	73	13.7	50.7	429	4.2	68.3	17.9	720	630	40.6
T_5-45x30 cm paired row (1,48,148 plants/ha	129	73	12.2	88.7	467	4.1	72.7	19.2	795	678	39.6
SEm±	3.3	0.5	0.4	1.8	12.3	0.04	1.1	0.5	19.0	17.6	1.2
CD (P=0.05)	9.9	NS	1.1	5.5	36.9	NS	3.2	1.5	57.4	53.1	NS

Table 2 Influence of planting geometry on pollen production in male parent (R-64NB) of RSFH-1 hybrid sunflower

Treatment	Pollen production/plant (mg) from first whorl of flower opening to last whorl of flower opening (1-12 days)												Total	Mean
	1	2	3	4	5	6	7	8	9	10	11	12		
T_0	47.5	77.7	87.7	96.0	96.0	82.0	75.0	60.0	42.0	25.5	15.7	7.5	712.7	59.4
T_1	35.2	63.5	73.7	82.3	84.0	70.0	61.0	51.7	42.0	23.7	15.5	8.0	610.7	50.9
T_2	41.5	67.7	78.0	85.5	86.7	73.7	65.3	49.7	39.5	22.7	15.3	7.7	633.5	52.8
T_3	31.5	64.0	72.0	80.5	78.5	65.7	56.3	46.3	40.5	19.7	14.0	2.3	571.3	47.6
T_4	49.5	73.7	84.5	90.5	91.3	80.0	69.5	58.5	39.0	25.5	15.5	6.5	685.0	58.1
T_5	40.0	64.0	76.5	81.0	81.3	68.3	61.3	48.5	41.3	21.3	14.5	1.0	598.7	49.9
Mean	39.9	68.5	78.7	85.9	86.3	73.3	64.7	52.5	40.7	23.1	15.1	5.5	635.3	33.3
SEm±													9.6	1.7
CD (P=0.05)													28.9	5.0

T_0-60x30 cm single row (55,555 plants/ha)
T_1-60x30 cm paired row (1,11,110 plants/ha)
T_2-60x20 cm single row (83,333 plants/ha)
T_3-60x20 cm paired row (1,66,666 plants/ha)
T_4-45x30 cm single row (74,074 plants/ha)
T_5-45x30 cm paired row (1,48,148 plants/ha

The yield and yield components of seed parent (CMS-103A) like number of filled seeds, seed set percentage, seed yield/plant, seed yield/ha, processed seed yield/ha and oil yield/ha were highest in treatment which received pollen from the restorer line planted at 60x20 cm paired row (Table 1). These results are in conformity with the findings of Kempegowda (1992), Rajashekhar (2000) and Kantharaju (2003) who reported that higher number filled seeds are due to sufficient amount of pollen grains available for successful pollination from increased number of pollen parents per unit area thereby decreasing the empty achenes in female line. They also reported that lower row proportion (female to male) increased the per cent seed set in sunflower. Rajashekhar (2000) and Salmana Sultana and Rajendra Prasad (2005) have reported that use of 100% pollen resulted in significantly highest seed yield/plant and per hectare over pollen mixed with filler material (25 to 50%). The increase in seed yield/ha may be attributed to more number of filled seeds, seed set per cent and seed yield/plant as noticed in the present study. The test weight and per cent oil content were higher due to lesser number of filled seeds in 60x30 cm single row (55,555 plants/ha). The higher oil content may be attributed to higher test weight and well developed endosperm rich in oil.

From the present study it is concluded that by increasing the plant population of non-branching restorer line (R-64NB) with spacing of 60x20 cm paired row within the recommended planting ratio of 3:1 female to male lines, maximum hybrid seed yield can be realised.

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Short communication

Effect of fertility on growth, yield and economics of sunflower, *Helianthus annuus* L.

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Sunflower responds to fertilizer application for high yield. Singh *et al.* (1999) reported that the sunflower hybrids require more nutrients than the varieties. This adds to additional expenditure. On the other hand, if the hybrids are not fertilized with optimum level of nutrients then the soil available nutrients may be greatly depleted. This requires a comparative study on the relative performance of a variety and hybrid grown under rainfed condition with different levels of fertilizers. Hence, this experiment was planned.

A field experiment was conducted at the students farm at the Agricultural College, Rajendranagar during *kharif*, 2004. The trial was laid out in a Randomized Block Design with 12 treatments and four replications. The sunflower variety Morden and the hybrid KBSH-1 were each fertilized with 6 levels of nutrients (Table 1). These 12 treatments were statistically evaluated by following the 2 x 6 factorial analysis. The crop was sown on 9th June, 2004. The soil was sandy loam having 0.40% organic carbon. The available nutrient status was low for nitrogen (168.9 kg/ha), medium for phosphorus (23 kg/ha P) and potassium (249.3 kg/ha K). The EC was 0.215 dS/m and the pH was 7.5. Rainfall of 484.8 mm was received in 26 rainy days during the 95 days growing period of variety modern, while 523.6 mm rainfall was disturbed in 29 rainy days during the 110 days growing period of the hybrid KBSH-1. There were no major dry spells exceeding a week.

The nitrogenous fertilizer was applied in two splits i.e., half nitrogen along with phosphorus and potassium of the respective treatment was applied basal at sowing and rest top dressed after one month. All the other recommended package of practices were followed. The oil content in seeds was estimated by Nuclear Magnetic Response Spectrophotometer as suggested by Tiwari et al. (1974).

The results showed wide variations in vegetative and reproductive growth of sunflower variety/hybrid (Table 1). The hybrid, KBSH-1 attained significantly more weight (165.3 cm), produced more number of 9.5 leaves/plant and accumulated phytomass of 127.2 g/plant. In contrast, Morden had a significantly low height of 109.0 cm, retained only 5.8 leaves/plant at harvest and accumulated 114.9 g phytomass/plant. The hybrid KBSH-1 and Morden displayed capitulii of same diameter with no statistically significant difference. But, the hybrid had an edge to produce significantly more number of seeds/capitulum with a higher test weight and yield/plant. However, seed yield of 1199 kg/ha from KBSH-1 was on par with seed yield of 1144 kg/ha from Morden. This variation in trend for 1 ha production could possibly be due to the inadequacy of sampling unit of 5 plants/plot confounded with the variable plant population in each plot at harvest despite a non-significant difference. The similar yielding ability of Morden as with the hybrid subjected to similar cultivation practices has also been ascertained by Hiremath *et al.* (1990). However, the hybrid had a tremendously high oil content of 43.1% and thereby produced more quantity of 516 kg oil yield/ha relative to 32.7% oil content and 374 kg oil yield/ha by Morden. Kene *et al.* (1992) and Malik *et al.* (2004) also recorded similar trends.

Sunflower responded to the application of fertilizers. The mean plant height, phytomass/plant, capitulum diameter, number of seeds/capitulum, test weight and yield/plant increased significantly by the application of 30:20:10 kg/ha NPK. The response was further significant by increasing the level of nutrients to 60:40:20 kg/ha. The mean seed yield of sunflower grown on native soil nutrients was 717 kg/ha. The yield increased to 1035 kg/ha by the application of 30:20:10 kg/ha NPK and to 1209 kg/ha when fertilized with 60:40:20 kg/ha NPK. The yield response was static with further incremental increase in the level of nutrients upto 150:100:50 kg/ha NPK.

The interactions were not significant. This imply that the trends to nutrient responses were alike for both morden and KBSH-1 when they were grown under similar soil, environmental and management conditions. Such comparative nutrient responses could not be spotted out from the previous literature. However, several reports indicate highly variable nutrient requirements for the same variety or hybrid grown in different climatic variations within the season, different soils and management practices within the same and different locations within and different agro-ecological regions of the country (Singh *et al.*, 1999; Taha *et al.*, 1999; Nanjundappa *et al.*, 2001; Reddy *et al.*,

2002; Muralidharudu *et al.*, 2003 and Malik *et al.*, 2004). The oil per cent of sunflower seed was not influenced by the application of different levels of fertilizers. The oil yield was also on par due to different fertility treatments. This was due to the lack of significant response in oil per cent and seed yield, since, oil yield is a product of these two parameters. Scheiner *et al.* (2002) and Malik *et al.* (2004) reported that the oil per cent in sunflower declined by the application of more than 60 kg N/ha. Tamak *et al.* (1997) reported that the application of 60 kg P_2O_5/ha increased the oil content significantly and highest oil content was found with the application of 90 kg P_2O_5/ha. But, the relative proportion of nutrients in our treatments did not bring a significant deviation probably due to their balanced interactive effects.

The cultivation expenses of the hybrid KBSH-1 were more due to the high cost of seed @ Rs. 150/kg compared to Rs. 60/kg of the morden. Gross returns increased with increasing level of nutrients upto 150:100:50 kg/ha NPK in both the genotypes. But, maximum profit of Rs. 9130/ha was realized from morden and Rs. 9394/ha from the hybrid KBSH-1 when they were fertilized with 90:60:30 kg/ha NPK. But, in light of the present day consciousness on low external input sustainable agriculture (LEISA) the application of 60:40:20 kg/ha NPK to morden appears judicious. The returns was per rupee of Rs. 1.28 with cost of cultivation of Rs. 6294/ha on this treatment was much higher than the diminution of returns with increasing level of more expensive and more profitable levels of fertilization/ha. Net profit of Rs. 1.29/rupee investment was realized from the hybrid KBSH-1 with still low level of fertilization at 30:20:10 kg/ha NPK. But, owing to its costly seed material, the cost of cultivation of Rs. 6397/ha was relatively more than that on morden fertilized with 60:40:20 kg/ha NPK (Table 2).

The study indicated that the sunflower variety morden matured early by 15 days produced seed yield on par and was equally profitable with the hybrid. The application of 60:40:20 kg/ha NPK is optimum. In events of dry spells during mid September the hybrid is likely to produce low yield due to 15 extra days needed for maturity than morden.

Table 1 Crop growth, yield components and yield of sunflower as influenced by genotypes and different levels of fertilizers

Treatment	Plant height (cm)	No. of levels/ plant	Dry weight (g/plant)	Capitulum *diameter* (cm)	Seeds/ capitulum	Test weight (g)	Yield		Oil	
							g/plant	kg/ha	%	yield/ha
Genotype										
Morden	101	6	114.9	14.6	697	41	26.7	1144	35.7	374
KBSH-1	165	10	127.2	14.3	860	45	31.9	1199	43.1	516
SEm±	1.6	0.4	2.0	0.3	20	0.2	1.1	34	0.8	16
CD (P=0.05)	4.7	1.1	5.7	NS	59	2.08	3.20	NS	2.22	48
Fertilizer (NPK kg/ha)										
0:0:0	110	7	66.6	10.8	522	31.93	15.96	717	38.28	274
30:20:10	127	8	105.1	13.4	629	40.32	24.65	1035	38.06	396
60:40:20	139	8	129.2	14.8	821	44.19	31.49	1209	38.28	463
90:60:30	139	8	136.6	15.6	891	47.81	34.29	1343	38.09	524
120:80:40	138	8	141.5	15.6	866	47.28	33.93	1335	39.98	499
150:100:50	142	9	147.1	16.6	893	48.96	35.53	1388	36.79	515
SEm±	2.8	0.7	3.4	0.6	35	1.25	1.92	60	1.32	28
CD (P=0.05)	8.1	NS	9.8	1.7	102	3.61	5.55	173	NS	83

Table 2 Economics of sunflower as influenced by genotypes and different levels of fertilizers

Treatment	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns	
			(Rs/ha)	Re investment
Morden				
0:0:0	4700	9103	4403	0.93
30:20:10	5497	11274	5777	1.05
60:40:20	6294	14385	8091	1.28
90:60:30	7091	16194	9103	1.28
120:80:40	7888	15363	7475	0.94
150:100:50	8685	16072	7387	0.85
KBSH-1				
0:0:0	5600	8805	3205	0.57
30:20:10	6397	14701	8304	1.29
60:40:20	7194	15862	8668	1.20
90:60:30	7991	17385	9394	1.17
120:80:40	8788	18073	9285	1.05
150:100:50	9585	18696	9111	0.95

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Short communication

Effect of intra row spacing and nitrogen application on the productivity of hybrid sunflower, *Helianthus annuus* L. sown on varied dates

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Sunflower (*Helianthus annuus* L.) is valued for its high quality edible oil possessing high oleic and linoleic acids, greater oxidative stability and anti-oxidant properties. Sunflower is a day neutral, photo and thermo-insensitive plant and, therefore, can be successfully grown in different seasons. However, under the agro-climatic conditions of Punjab, it gives higher and stable yields during spring season when abundance of honey bees ensure pollination and seed setting in this cross pollinated crop. Earlier studies indicated for higher yields of long duration (about 120 days or more) varieties/hybrids with December-January sowing and consistent reductions in seed yield with further delay in sowing (Sidhu and Kolar, 1996). However, it takes long time (2-3 weeks) for seed germination and requires efforts to protect the seedlings from low temperature/frost during winter. Sowing of sunflower is often delayed due to late harvesting of crops in intensive cropping systems as well as due to non-availability of seed in the market. With the availability of short duration hybrid PSFH 118 (98 days), the yield loss resulting from delayed sowing may be minimized. However, no such information is available about the effect of delayed planting on the seed and oil yield of short duration sunflower. Therefore, this investigation was conducted to study (i), the effect of sowing time on productivity of short duration and short statured sunflower hybrid, PSFH 118, (ii) whether yield reduction caused by delayed planting can be compensated by increasing plant population, and (iii) the influence of nitrogen application on the productivity of varied plant populations of short duration sunflower hybrid.

The experiment was conducted in spring 2004 at the Punjab Agricultural University, Ludhiana (30 56'N, 75 52'E, 247 m above msl) on loamy sand soil, neutral in reaction (pH 7.5), free from salts (0.2 dS/m), low in organic carbon (0.21%), medium in available phosphorus (17.5 kg/ha) and medium in available potassium (210 kg/ha). The treatments replicated thrice were laid out in a Split-Split Plot Design with three sowing dates (3 February, 16 February and 1 March) allocated to the main plots, three intra-row spacings (15, 22.5 and 30 cm) in the sub-plots and three doses of nitrogen (60, 80 and 100 kg/ha) assigned in the sub-sub plots. The crop was sown on ridges made 60 cm apart in the east-west direction. Half dose of nitrogen in the form of urea along with 30 kg P_2O_5/ha as single super phosphate was uniformly applied at sowing time. Remaining half dose of nitrogen as per treatments was top dressed after thinning done at 30 days after sowing followed by irrigation.

Sowing of sunflower on 3 February took significantly more number of days to initiation of flowering, produced significantly taller plants with markedly greater stem girth, head diameter and 100-seed weight compared to delayed sowings of 16 February and 1 March (Table 1). Consequent upon improvement in yield attributes, seed yield in case of 3 February sowing was significantly higher than other delayed sowing dates. Seed yield in case of 16 February sowing (898 kg/ha) was only 59.6% of that obtained with 3 February sowing (1506 kg/ha) and was reduced to 695 kg/ha (46.1%) with further delay in sowing on 1 March. Furthermore, seed yield in case of 1 March sowing was 29.2% lower than 16 February sowing. There was significant reduction in oil content and oil yield with successive delay in sowing. The oil yield (567 kg/ha) obtained in case of 3 February sowing was significantly superior to 16 February (275 kg/ha) and 1 March sowing (200 kg/ha). Sowing time influences crop yield through its influence on phenological and morphological development of plant. Growth period of sunflower was longer when sown under low temperature conditions and the crop matured earlier with delay in sowing (Santamaria *et al.*, 1991). Under late sown conditions, the vegetative and reproductive stages of crop coincide with higher temperature and lower relative humidity, shortening the crop growth period and reduced pollinations resulting in more number of empty achenes and consequently lower yield compared to early sowing (Bange *et al.*, 1997). Pol *et al.* (1990) also reported highest seed yield with 11 February sowing which decreased with successive delay in sowing up to 11 May under similar agro-climatic conditions. Ramesh *et al.* (2005) reported reduction in growth parameters while Arthanari and Balasubramanian (2005) reported declining seed yield of sunflower with delay in sowing. As the heat units increased with delayed

sowing, the crop duration was sharply reduced leading to less time available to crop for photosynthetic utilization and ultimately resulted in lower yield compared to earlier sowing dates (Ramesh *et al.*, 2005). Naresh Kumar (2005) reported differences in growth and growing degree days required to attain different growth stages in sunflower sown on different dates and such differences were more during grain filling period than vegetative period. Grain filling period of late sown crop was reduced resulting in lower yield in late sown crop than earlier sowing dates.

Different intra-row spacings failed to influence growth, ancillary characters and seed yield. However, oil yield recorded with closer intra-row spacing (15 cm) was significantly higher than wider spacing i.e. 30 cm but comparable to 22.5 cm spacing (Table 1).

Though non-conspicuous, seed yield decreased with increasing intra-row spacing i.e. decreasing plant population. Sunflower has wider plasticity for adjustment to varying plant populations and spacing. These results are in line with those reported by Rao and Reddy (1982).

Table 1 Influence of sowing dates, intra-row spacing and nitrogen application on the ancillary characters, seed and oil yield of hybrid sunflower

Treatment	Days to flower initiation	Plant height (cm) at maturity	Stem girth (cm) at maturity	Head diameter at maturity (cm)	100-seed weight (g)	Seed yield (kg/ha)	Oil yield (kg/ha)
Sowing date							
3 February	61.2	127.2	4.94	13.6	5.54	1506	567 (37.7)*
16 February	56.7	100.2	3.75	8.5	3.88	898	275 (30.6)
1 March	55.6	93.7	3.67	8.8	3.94	695	200 (28.8)
CD (P=0.05)	1.05	9.7	0.26	1.7	0.41	319	115 (0.5)
Intra-row spacing (cm)							
15	57.3	109.2	4.05	9.9	4.32	1085	365 (32.5)
22.5	57.5	106.0	4.11	10.2	4.46	1026	348 (32.6)
30	58.6	105.9	4.20	10.8	4.58	988	329 (32.0)
CD (P=0.05)	NS	NS	NS	NS	NS	NS	24 (0.4)
Doses of nitrogen (kg/ha)							
60	57.7	105.2	4.03	9.8	4.28	969	329 (32.6)
80	57.4	106.1	4.09	10.2	4.55	1036	346 (32.0)
100	58.3	109.8	4.25	10.9	4.54	1093	367 (32.5)
CD (P=0.05)	NS	3.2	NS	0.6	0.17	56	19 (0.4)

* Values in parenthesis indicate per cent oil content
CD (P=0.05) Sowing dates x intra row spacing 134 41

Application of 100 kg N/ha resulted in significantly taller plants, more head diameter and 100-seed weight compared to 60 kg N/ha (Table 1). Significantly higher seed (1093 kg/ha) and oil yield (367 kg/ha) were obtained with 100 kg N/ha over 60 and 80 kg N/ha. Application of 80 kg N/ha also resulted in significantly higher seed yield than 60 kg N/ha (969 kg/ha) whereas such an increase for oil yield was not significant. Thus, application of 100 kg N/ha resulted in 6.1% higher oil yield over 80 kg N/ha which in turn was superior to 60 kg N/ha by 5.1%. Vivek and Chakor (1992) also reported increased seed yield with increased doses of nitrogen.

Interaction of sowing dates and intra row spacing was significant for both seed yield and oil yield. In case of 3 February sowing, the seed yield increased with increased intra-row spacing but all the spacings were at par whereas

the highest but non-significant increase in oil yield was recorded with intra-row spacing of 22.5 cm. However, seed and oil yields significantly increased with each successive reduction in intra-row spacing i.e. increasing plant population in case of 16 February sowing while in 1 March sowing, differences in seed yield due to varied intra row spacings were non-conspicuous. In all spacings, seed and oil yield decreased with delay in sowing and such a reduction in 16 February sowing was significant over 3 February sowing. Reduction in seed yield in case of 1 March sowing over 16 February sowing was also significant except in intra row spacing of 30 cm.

Thus, delay in sowing resulted in reduced seed and oil yields. Hence, it may be concluded that for higher yields, short duration sunflower hybrid should be sown in first week of February with a spacing of 60 cm x 15 cm and nitrogen application of 100 kg/ha on poor fertility loamy sand soils.

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Short communication

Seed yield, petal yield and economics of safflower, *Carthamus tinctorius* L. as influenced by irrigation schedule

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India is the largest producer of safflower in the world, grown on an area of 5.4 lakh ha with production of 4.7 lakh tonnes. Maharashtra and Karnataka states account for 73 and 22% of acreage, 68 and 30% of production, respectively. Of the total area contributed by Maharashtra state, Marathwada contributes 40 to 45% area of safflower.

Petal yield of safflower is another good alternative source of income to farmers. Safflower petals can be used in preparation of refreshing herbal tea. Florets used to colour and flavour soups, rice, souses, bread and pickles. The sweet smelling tea contains 16 amino acids, minerals and vitamins, *i.e.*, B_1, B_{12}, B_2, *C* and *E*. The use of petal as medicinal preparation reported to activate blood circulation, regulates menstruation cycle, reduces pain and cure fractures.

About 90% of the oilseeds cultivation in India is under rainfed conditions. Irregular rains and inadequate irrigations at critical growth stages largely affect the final yield. The information on scheduling irrigation and the important and most sensitive growth stages of safflower is meager. Hence, there is an urgent need to know irrigation schedule, critical growth stages of safflower for minimal irrigation so as to make a success under command areas of Jayakwadi and Purna.

A field experiment was conducted on medium, dark grey coloured and about 100 cm deep soil at Marathwada Agricultural University, Parbhani during *rabi*, 2003-04. The soil was clayey in texture with slightly alkaline in reaction (pH 8.3). It was low in available nitrogen (112.5 kg/ha), medium in phosphorus (18.9 kg/ha) and high in potassium (514.7 kg/ha). The experiment was laid in Randomized Block Design with three replications, comprising of 9 treatments of irrigation schedules. Genotype NARI-6 was sown by dibbling the seed at 20 cm plant and 45-90 cm row spacing. The method of planting was skip row planting. The gross and net plot size was 4.05 x 6.0 m and 2.7 x 5.2 m, respectively. Irrigations were applied to safflower in skip row furrow method of planting (45-90 x 20 cm). In this method one row after every two row is skipped and a furrow is opened in between skipped row for giving irrigation 97.2 mm water was applied per irrigation. The field capacity at the depth 15-30 cm and 30-45 was 30.30% and 32.30%, respectively. The PWP was 12.9% and 13.10% at the depth 15-30 and 30-45 cm, respectively. The sowing date was 27.10.2003 and the harvesting date was 10.03.2004. The plant population was 76,923/ha. The complete dose of phosphorus (40 kg P_2O_5/ha) along with half dose of nitrogen (30 kg N/ha) as per recommendations was applied.

Irrigating safflower at rosette + branching + flowering + seed development stage (T_9) recorded significantly highest weight of capitula, number of seeds/capitulum, seed weight/plant, test weight and petal yield over rest of the treatments. Among one irrigation treatment, application of irrigation at rosette stage (T_2) was found to be significantly superior for producing yield attributes. Patel and Patel (1993) also observed the increase in yield attributes due to irrigation schedules.

Seed yield is the function of yield attributing characters. Application of irrigation at rosette + branching + flowering + seed development stage (T_9) recorded significantly higher seed, petal and oil yield than other irrigation treatments. It was followed by treatment T_8. Irrigating safflower at rosette stage recorded significantly highest harvest index. The differences in yield of safflower were also noticed by many research workers (Bhalerao *et al.*, 1993; Ved Singh *et al.*, 1995 and Chatol *et al.*, 1998).

The mean cost of cultivation of safflower was Rs. 186401/ha for seed and petal collection. Irrigating safflower at rosette + branching + flowering + seed development stage (T_9) recorded significantly higher total net returns (Table 2). It was followed by application of three irrigations at rosette + branching + flowering stage. Irrigating safflower at rosette stage (T_2) and rosette + branching (T_5) recorded significantly higher total net returns under minimal irrigation and two irrigations, respectively. Scheduling four irrigations at rosette + branching + flowering + seed development stage (T_9) recorded maximum benefit : cost ratio than control and irrigation at branching and flowering stage. Most important and critical growth stage was found to be rosette stage (30-35 DAS). By adopting skip row method of planting, there is saving of water by 33% over flood irrigation.

It could be inferred that if adequate irrigations are available, scheduling irrigation to safflower crop at rosette + branching + flowering + seed development stage is necessary for obtaining higher seed, petal, oil yield, total net returns and benefit : cost ratio. If only two irrigations are available irrigating at rosette + branching is beneficial and under minimal irrigations, one irrigation at rosette stage is beneficial.

Table 1 Yield attributing characters and yield of safflower as influenced by irrigation schedules

Treatment	Weight/ capitulum (g)	No. of seeds/ capitulum	Seed weight/ plant (g)	Test weed weight (g)	Petal yield/ plant (g)	WUE (kg/mm/ ha)	No. of irrigations	Seed yield (kg/ha)	Petal yield (kg/ha)	Harvest index (%)	Oil yield (kg/ha)
T_1 : Control	34.7	18.3	12.0	34.9	1.24	-	-	859	96.0	23.05	240
T_2 : Irrigation at rosette ®	56.3	22.5	21.1	37.0	2.45	13.72	1	1334	121.0	29.98	388
T_3 : Irrigation at branching (B)	55.8	21.8	20.5	36.4	2.40	11.51	1	1119	119.5	26.11	318
T_4 : Irrigation at flowering (F)	36.8	19.0	14.8	36.0	1.34	9.23	1	898	103.8	29.83	255
T_5 : Irrigation at R + B	72.6	29.8	35.7	39.6	3.80	8.91	2	1734	213.5	26.25	510
T_6 : Irrigation at R + F	65.6	26.2	26.3	38.0	2.71	7.52	2	1463	175.4	27.32	428
T_7 : Irrigation at B + F	62.7	25.0	24.4	38.0	2.36	7.44	2	1447	162.9	27.43	422
T_8 : Irrigation at R + B + F	73.0	31.6	36.4	40.0	3.90	6.32	3	1843	214.3	26.70	546
T_9 : Irrigation at T_8 + seed development stage	76.1	32.6	38.6	41.3	4.00	5.34	4	2077	233.2	28.70	625
SEm±	1.3	0.7	1.1	0.4	0.32			80.8	4.19	0.65	28.0
CD (P=0.05)	4.1	2.3	3.5	1.3	1.00			241.9	14.8	2.00	84.1

Table 2 Economics of safflower as influenced by irrigation schedules

Treatment	Gross returns (Rs/ha)	Cost of production (Rs/ha)	Net return (Rs/ha)	B:C ratio
T_1 : Control	19908	13720	6188	1.45
T_2 : Irrigation at rosette ®	28108	15720	12388	1.78
T_3 : Irrigation at branching (B)	25373	15611	9762	1.62
T_4 : Irrigation at flowering (F)	21126	14516	6640	1.45
T_5 : Irrigation at R + B	42158	22445	19713	1.87
T_6 : Irrigation at R + F	35091	19774	15371	1.77
T_7 : Irrigation at B + F	33654	18903	14751	1.78
T_8 : Irrigation at R + B + F	43546	22751	20795	1.91
T_9 : Irrigation at T_8 + seed development stage	47249	24327	22922	1.94
SEm±			1370	0.39
CD (P=0.05)			4120	1.17

Safflower seed Rs. 1200/q; Petals Rs. 100/kg

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Short communication

Studies on survey, surveillance and mapping of groundnut rust endemic areas in northern Karnataka

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Groundnut is one of the main *kharif* crops of northern Karnataka which is grown both under rainfed and irrigated conditions. The commonly cultivated groundnut varieties are highly susceptible to foliar diseases. Among foliar diseases, rust caused by *Puccinia arachidis* Speg., is an economically important disease of groundnut in the region. The yield losses upto 29-42% due to rust have been reported (Krishna Prasad *et al.*, 1979; Siddaramaiah, 1983). The disease appeared in moderate form year after year causing losses in the year till 1999. But, in recent years, the disease is appearing in severe form and has become one of the major constraints for groundnut cultivation. Recently, 11-80% and 41-80% disease index of rust have been reported in Koppal and Raichur districts, respectively (Anonymous, 2002). A number of management approaches leading to management of the groundnut rust have been evaluated and recommended (Vidhyasekaran, 1981; Adiver *et al.*, 1995; Jadeja *et al.*, 1999). But, the management under epidemic form is more important to reduce more losses in yields of groundnut. Therefore, it is necessary to know the severity of the disease in different localities of the region to identify, develop and recommend cost effective methods suitable to each location looking into the prevailing conditions. Keeping this in view, the present investigation was intended to provide the data on severity of the disease and thereby mapping of groundnut rust endemic areas in northern Karnataka.

A fixed plot survey was carried out in groundnut growing areas of northern Karnataka to know the severity of rust during *kharif*, 2002 and 2003. Farmers fields in different villages of Deodurga, Sindhanur, Lingasgur, Manvi and Raichur of Raichur district; Gangavati, Koppal, Kushtagi and Yelburga taluks of Koppal district; Bhalki and Bidar taluks of Bidar district; Aland, Gulbarga, Shahapur and Shoropur taluks of Gulbarga district; Bagalkot and Hungund taluks of Bagalkot district, Gadag taluk of Gadag district; Dharwad and Hubli taluks of Dharwad district; Bijapur and Muddebihal taluks of Bijapur district; Haveri taluk of Haveri district; Siruguppa, Hospet and Bellary taluks of Bellary district and Gokak taluk of Belgaum district were covered under survey programme. In each village, five groundnut fields were selected randomly on both sides of the road and 65 to 85 days old groundnut crops were observed for rust incidence. In each field, ten groundnut plants were randomly selected and disease index of rust was recorded by following 1-9 point modified scale as per Wheeler, 1969; Subrahmanyam *et al.*, 1995). Mapping of groundnut rust endemic areas was done on per cent disease severity basis.

The results indicated that, rust of groundnut was prevalent in very severe form during *kharif*, 2002 and 2003 in groundnut growing areas of northern Karnataka (Table 1 and Fig. 1 and 2). The average maximum severity was comparatively more during 2003 (75.5%) than 2002 (63.7%). Similarly, the average minimum severity of 38.5% was recorded during 2003 when compared to 34.6% during 2002. Among 11 districts surveyed, the average maximum disease severity was recorded in Raichur followed by Gulbarga and Koppal and the least was in Dharwad. During 2002, the maximum average disease severity of 63.7% was recorded in Raichur district followed by Gulbarga (57.2%) and Koppal (56.2%) and Dharwad district recorded the least average severity of 36.3%. While, it was as high as 75.5% in Raichur district followed by Gulbarga (70.5%) and Koppal (70.5%) during 2003.

The rust severity varied from locality to locality, because of type of variety grown, environmental conditions, cropping pattern and build up of inoculum. It was observed that, disease severity was more in irrigated crop than in rainfed. This may be attributed to more humidity and cooler temperatures in the crop canopy which confirms the findings of Krishna Prasad *et al.* (1979). The average disease severity varied in various locations in different districts owing to varied agro-climatic conditions and also different cultivars used. In northern Karnataka, the average maximum disease severity was found more in Raichur district followed by Gulbarga and Koppal and least in Dharwad. Such variation in rust severity and wide spread nature have been reported by earlier workers (Subrahmanyam *et al.*, 1979; Ghewande and Misra, 1983;

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Table 1 District-wise per cent disease index of groundnut rust during *kharif*, 2002 and 2003 in northern Karnataka

District	Average per cent disease index (PDI) of rust			
	2002		2003	
	Maximum	Minimum	Maximum	Minimum
Bagalkot	53.6	49.8	61.6	61.5
Belgaum	37.1	35.1	38.5	36.2
Bellary	49.2	40.0	52.5	40.6
Bidar	43.0	37.8	56.5	46.6
Bijapur	46.1	38.8	51.0	42.0
Dharwad	36.3	34.6	39.2	39.1
Gadag	40.0	40.0	44.6	44.6
Gulbarga	57.2	56.6	71.0	69.7
Haveri	41.6	39.3	43.7	39.9
Koppal	56.2	55.2	70.5	57.9
Raichur	63.7	56.3	75.5	73.3
State average	63.7	34.6	75.5	38.5

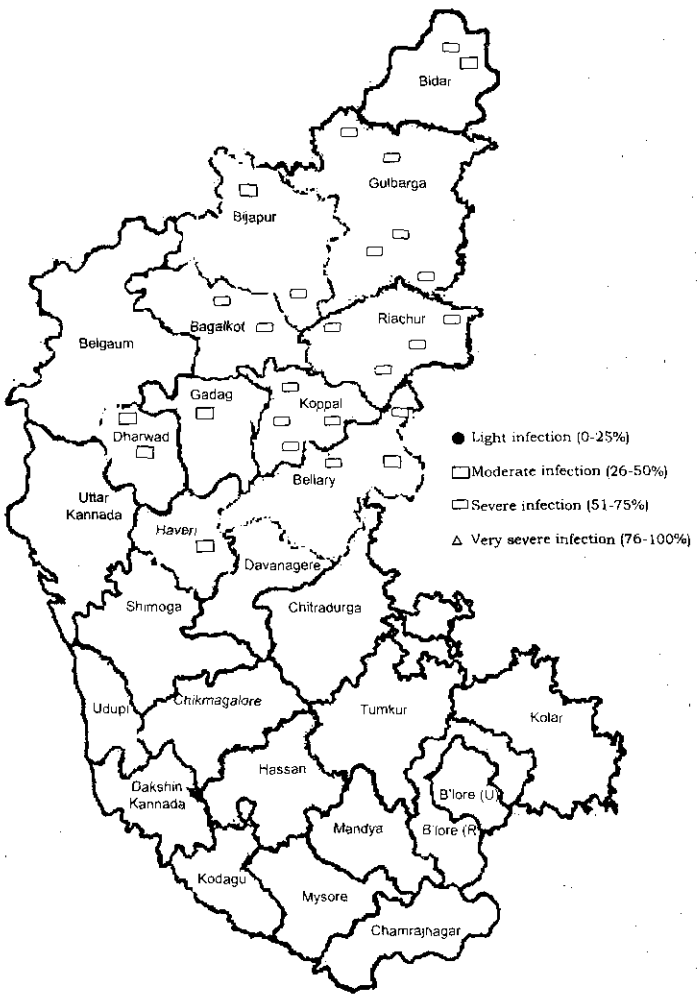

Fig. 1. Severity of groundnut rust (*P. arachidis*) in different districts of northern Karnataka during *kharif*, 2002

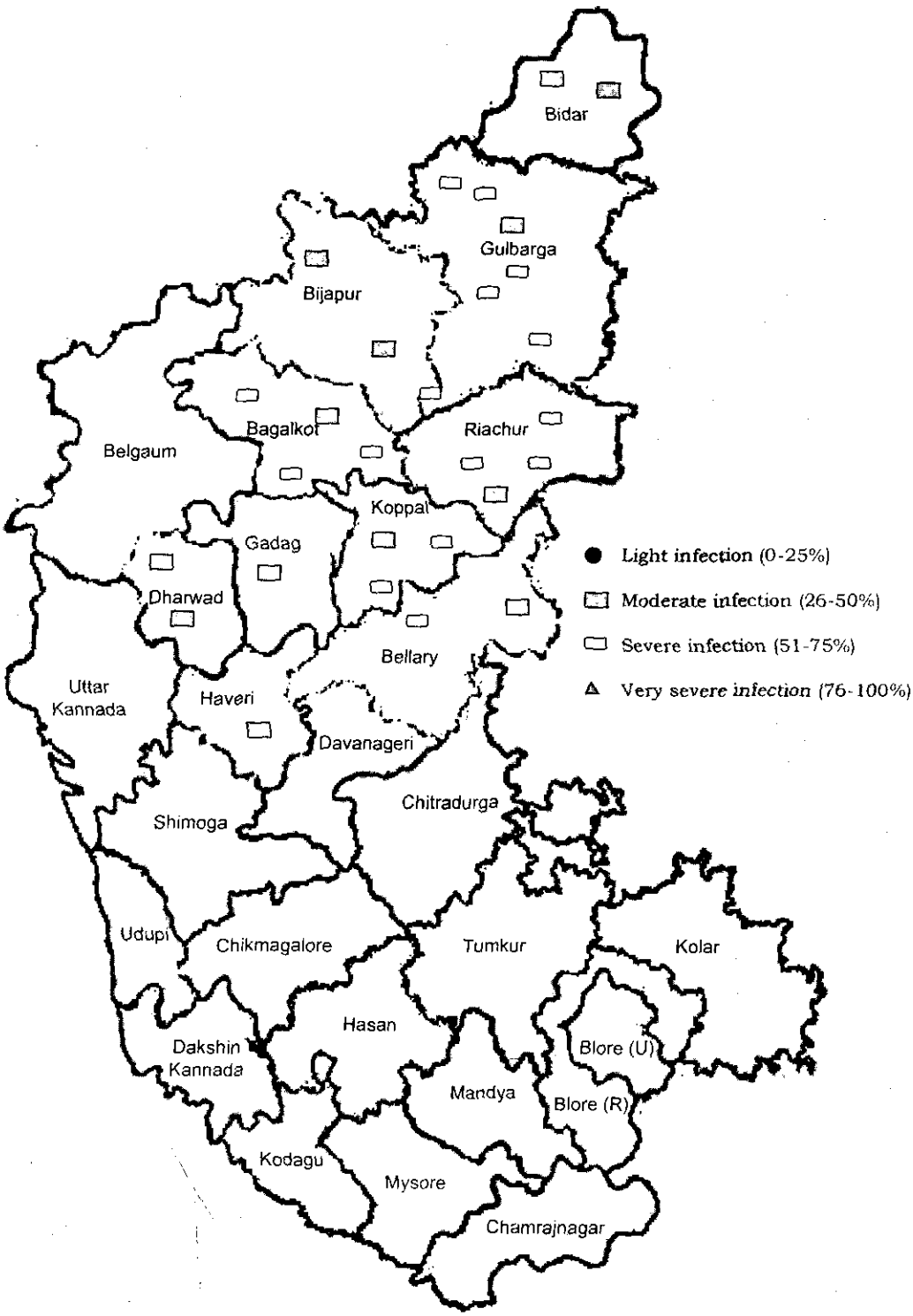

Fig. 2. Severity of groundnut rust (*P. arachidis*) in different districts of northern Karnataka during *kharif*, 2003

Siddaramaiah *et al.*, 1979). Further, the maximum disease severity of rust in Raichur, Koppal and Gulbarga districts may be attributed to extensive and continuous cropping of groundnut. The results are in agreement with the findings of Subrahmanyam *et al.* (1979) and Subrahmanyam and Mc Donald (1983). Lower minimum disease severity in Dharwad district may be attributed to cultivation of resistant/tolerant varieties and groundnut as sole crop under rainfed conditions and early sowing (May last week to June first week). Thus, the increasing trend in disease severity of groundnut rust can be attributed to late sowing (Late June to July) due to irregularity in supply of water from command area canals and unpredictable start of rainy season and unawareness in application of suitable fungicides and also the cultivation of highly susceptible varieties of groundnut.

Hence, the present studies indicated that Raichur may be identified as 'hot spot' for the incidence of rust of groundnut. Further, rust severity varied from locality to locality and was more in irrigated crop conditions than in rainfed crop. Therefore, farmers in these endemic areas have to take up control measures invariably to reduce more losses in pod and haulm yields of groundnut during *kharif* season.

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Short communication

Screening of different mustard varieties for resistance against mustard aphid, *Lipaphis erysimi* (Kalt.)

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Mustard, *Brassica juncea* (Linn.) Czern. & Coss. is an important oilseed crop of family Cruciferae. It is mainly grown in *rabi* season as oilseed, condiment and medicinal crop. The green leaves and stems of mustard are good source of green vegetables and fodder. The oil content in seeds ranges from 32 to 42%, used for edible purposes. In India, important mustard growing state are Rajasthan, Uttar Pradesh, Madhya Pradesh, West Bengal, Punjab and Assam. The area under the crop in Rajasthan was 1.19 m. ha with an annual production of 1.17 m. tones and average productivity of 989 kg/ha during the year 2002-2003. Mustard aphid, *Lipaphis erysimi* Kalt. is one of the most serious pest of this crop (Rai, 1976) causing 9.0-95.0% losses in seed yield and on an average 15.0% loss in its oil yield. Both nymph and adult stages of this pest cause quantitative and qualitative losses to crop. In integrated pest management programme growing of resistance varieties against insect, is one of the most important tool in the management of aphid without additional cost.

The field experiment was conducted during *rabi* 2003-04 at S. K. N. College of Agriculture, Jobner- Rajasthan. The experiment was laid out in Randomize Block Design with three replications and 10 cultivars. The plot size was 4 x 3 m^2 with row to row and plant to plant distance of 30 cm and 10 cm, respectively. The crop was sown on 5th November 2003. The observations on the population of aphid were recorded at weekly interval from the appearance of aphid to harvesting of the crop. The aphids were counted visually on upper 10 cm shoot of five randomly selected tagged plants (Bakhetia and Sandhu, 1973). The total phenols and free amino acids were estimated from leaf of the plant at the time of peak aphid population. Total phenol and free amino acids were estimated as per standard method. The simple correlation was computed between aphid population and biochemical parameters.

None of the variety was found completely free from aphid infestation. Aphid infestation started from first week of January and reached to its peak in the first week of February and continued up to middle of March. The minimum mean aphid population (16 aphids/plant) was observed on variety T-59 (Varuna), while maximum (56 aphids/plant) on RZM-1359. The population was comparatively less on varieties T-59 (Varuna) and Bio-902 could be categorized as least preferred. On varieties *viz.*, TM-4, PCR-7, RH-30, RH-781 and PBR-91 the aphid population was of middle order and thus categorized as moderately preferred. The aphid population was more on varieties GM-2, JM-1 and RZM-1359 which was recognized as highly preferred varieties. The present investigation corroborates with those of Vir *et al.* (1990), Jat *et al.* (1993) and Takar *et al.* (2003) who observed that varieties T-59 (Varuna), Bio-902 and PCR-7 were highly resistant to mustard aphid.

The morphological character of plant *viz.*, plant height ®= - 0.988), siliqua/plant ®= - 0.946) and seeds/siliqua ®= - 0.965) were negatively correlated with the peak aphid population. An increase in aphid population was responsible for reduction of plant height, siliqua/plant and seeds/siliqua. These results are in conformity with those of Malik and Deen (1998).

The total phenols was negatively correlated ® = -0.990) while, free amino acids was positively correlated ® = 0.992) with aphid population. The minimum aphid population was recorded in variety T-59 (Varuna) which had highest of total phenols and lowest of free amino acids (4.52 % and 1.30 %) whereas, the maximum aphid population was found in variety RZM-1359 which had lowest of total phenols and highest of free amino acids (2.97 % and 2.18 %).

Sachan and Sachan (1991) and Ram Dhari *et al.* (1995) also reported the negative correlation between total phenols and mustard aphid population and Malik (1988) reported positively correlation between free amino acids and aphid population.

Table 1 Weekly mean aphid, *L. erysimi* population/plant (10 cm top shoot) on different mustard varieties

Variety	08.01.04	15.01.04	22.01.04	29.01.04	05.02.04	12.02.04	19.02.04	26.02.04	05.03.04	Mean
PBR-91	7.46 (2.82)	23.60 (4.90)	44.80 (6.72)	68.60 (8.30)	92.93* (9.60)	71.13 (8.44)	36.13 (6.06)	17.46 (4.22)	3.46 (1.99)	40.62
GM-2	8.20 (2.95)	31.00 (5.60)	63.80 (8.01)	74.40 (8.64)	106.93 (10.35)	81.66 (9.05)	39.20 (6.28)	24.80 (5.00)	4.40 (2.21)	48.27
TM-4	5.86 (2.52)	18.60 (4.36)	35.13 (5.96)	51.13 (7.18)	71.46 (8.48)	55.07 (7.44)	25.46 (5.09)	14.40 (3.84)	2.60 (1.76)	31.08
JM-1	9.13 (3.10)	25.80 (5.11)	56.66 (7.55)	72.40 (8.53)	107.93 (10.41)	85.40 (9.26)	44.46 (6.70)	26.40 (5.17)	6.33 (2.61)	48.28
T-59	2.20 (1.64)	7.66 (2.85)	17.66 (4.25)	26.33 (5.17)	46.20 (6.83)	32.00 (5.70)	8.66 (2.99)	1.46 (1.40)	0.00 (0.71)	15.78
RH-781	6.86 (2.71)	24.00 (4.95)	54.40 (7.40)	62.80 (7.95)	84.13 (9.20)	64.67 (8.06)	32.13 (5.70)	18.67 (4.36)	3.40 (1.97)	39.01
PCR-7	5.20 (2.39)	12.26 (3.56)	24.33 (4.98)	38.60 (6.24)	56.00 (7.50)	38.60 (6.24)	16.53 (4.10)	5.33 (2.40)	1.60 (1.45)	22.06
Bio-902	3.00 (1.87)	9.00 (3.08)	20.26 (4.55)	30.80 (5.58)	48.46 (6.99)	34.00 (5.87)	10.20 (3.24)	2.26 (1.64)	1.00 (1.22)	17.67
RZM-1359	11.80 (3.51)	34.53 (5.90)	64.93 (8.08)	84.26 (9.20)	111.66 (10.59)	91.53 (9.59)	50.26 (7.12)	32.60 (5.74)	8.40 (2.98)	55.78
RH-30	6.33 (2.61)	13.40 (3.70)	26.53 (5.19)	40.80 (6.41)	58.53 (7.68)	44.07 (6.67)	22.66 (4.79)	9.20 (3.10)	2.13 (1.62)	24.92
SEm±	0.21	0.26	0.27	0.27	0.28	0.29	0.30	0.28	0.19	-
CD (P=0.005)	0.62	0.77	0.80	0.79	0.83	0.86	0.89	0.89	0.56	-

Figures in parenthesis are root x+0.5 transformed values; * = Peak aphid population during the crop season

Table 2 Effect of morphological and biochemical characters of plant on aphid, *L. erysimi* population

Variety	Aphid population	Plant height (cm)	Siliqua/ plant	Seeds/ siliqua	Total Phenol (%)	Free amino acid (%)
PBR-91	93	140	158	8	3.6	1.8
GM-2	106	134	145	8	3.1	1.9
TM-4	71	143	161	9	4.0	1.6
JM-1	107	133	141	8	3.0	2.0
T-59	96	152	193	11	4.5	1.3
RH-781	84	142	158	8	3.7	1.8
PCR-7	56	147	169	11	4.2	1.4
Bio-902	48	151	180	11	4.4	1.3
RZM-1359	112	131	139	7	2.9	2.1
RH-30	59	146	167	9	4.1	1.4
Correlation coefficient with aphid population		-0.988*	-0.946*	-0.965*	-0.990*	0.992*

* Significant at 5% level

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Short communication

Influence of *Pseudomonas fluorescens* on root knot nematode, *Meloidogyne arenaria* egg hatching, juvenile immobility and penetration into roots of groundnut, *Arachis hypogaea* L.

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Root knot nematode, *Meloidogyne arenaria* is a serious limiting factor in groundnut production. It causes extensive damage to groundnut pegs and prevents the pod development. Nematode control with use of chemicals is effective in soil but it creates environmental problems. Recently the use of bio-control agents like fluorescent pseudomonads for nematode control have got worldwide recognition (Spiegel *et al.*, 1991; Siddiqui *et al.*, 1999). Hence an attempt has been made to test the effect of *Pseudomonas fluorescens* on *M. arenaria* egg hatching, juvenile immobility and juvenile penetration into roots of groundnut cv. CO-3 during 2005 at Agricultural Research Station, Kadiri, Andhra Pradesh.

Hatching study: Four isolates of *P. fluorescens viz.*, Pf1 (TNAU strain), Pf CBE (Coimbatore strain), Pf BSR (Bhavanisagar strain) and Pf POL (Pollachi strain) were grown in King's B medium. For multiplication of *P. fluorescens* strains, King's B broth was prepared without addition of agar and the loopful of above isolates were inoculated to the broth in Erlenmeyer flasks aseptically and allowed to multiply in a rotary shaker for 48h at room temperature (28±2°C). After 48h the culture was centrifuged at 5000g for 15 minutes. The supernatant was diluted with 5 ml of distilled water and passed through 0.2µ filter for making cell free culture filtrate. Bacterial culture filtrate was taken in Petri dishes and egg masses (uniform size) of *M. arenaria* were transferred @ 10 egg masses/petri dish. Distilled water served as control. Number of juveniles hatched from egg masses were counted at 12 h interval for three days.

Immobility assay: For testing the effect of *P. fluorescens* on *M. arenaria* immobility, strain Pf1 multiplied in King's B medium and culture filtrate was collected, passed through 0.2µ filter and stored in refrigerator. Hundred second stage infective juveniles were exposed to culture filtrate at 25, 50, 75 and 100% concentration and distilled water served as control. Immobile juveniles were counted at 24 and 48h after exposure. Immobile nematodes were also transferred to distilled water to assess the recovery of juveniles.

Penetration study: To study the effect of *P. fluorescens* on juvenile penetration into groundnut roots, glass tubes of 7.5 cm length and 2.5 cm diameter were sterilized in oven and filled with sterilized river sand. Surface sterilized groundnut seeds were treated with *P. fluorescens* strain Pfl @ 25 ml inoculum (10^8cfu/ml)/kg seed. Seeds were sown at the rate of four seeds per tube. Untreated seeds served as control. Tubes were inoculated with 200 juveniles per tube at one week after sowing. Plants were uprooted and roots were stained by acid fuchsin and examined under stereozoom microscope to count the number of juveniles penetrated into roots of groundnut. Observation was made at 24h interval for seven days.

All the four isolates tested were inhibits egg hatching to a varying degree. Egg masses exposed to Pfl strain revealed maximum inhibition in hatching to the tune of 67.9% and it is followed by Pf CBE, Pf BSR and Pf POL (Table 1).

Infective juveniles of *M. arenaria* were exposed to Pfl culture filtrate become immobile at 24 and 48h of exposure. The juvenile immobility was 78.3% in 100% concentration of culture filtrate at 24h exposure. At 48h exposure showed 50% immobility in 25% concentration. When the nematodes were retransferred to distilled water, the recovery was less in nematodes treated with culture filtrates (Table 2). Similar increase in juvenile mortality of M. incognita, *Heterodera cajani, H. zeae* and *H. avenae* when exposed to culture filtrates of *P. fluorescens* was observed by Gokte and Swarup (1988).

Seed treatment with Pfl strain (10^8cfu/ml) significantly reduced the nematode penetration into roots compared to untreated plant. The reduction in penetration was 22.2, 27.8, 37.5, 36.4, 34.3 and 31.6% over control at 1, 2, 3, 4, 5 and 6 days after nematode inoculation respectively (Table 3). Oostendorp and Sikora (1990) reported that the decrease in nematode penetration due to *P. fluorescens* treatment in the case of sugar beet cyst nematode. Similarly 46% reduction of root knot nematode, *Meloidogyne arenaria* population in Pf1 treated groundnut plants was recorded by Kalaiarasan *et al.* (2001). The

mechanism responsible for the reduction in nematode penetration was attributed to the ability of the bacterium to envelope or binds to root surface lectins, thereby interfering with normal host recognition by the nematode.

In conclusion *P. fluorescens* can inhibit egg hatching, induce juvenile immobility and interferes in juvenile penetration into host root system. These are all the necessary attributes of a successful nematode biocontrol agent. Hence *P. fluorescens* can be used as a biocontrol agent in controlling nematode problems in groundnut growing areas.

Table 1 Effect of different isolates of *P. fluorescens* on hatching of *M. arenaria*

Treatment	Number of juveniles hatched (h)					
	24 hrs	36 hrs	48 hrs	72 hrs	96 hrs	Mean
Pf1	50.8 (41.8)	61.8 (34.0)	73.5 (31.8)	82.5 (29.5)	92.5 (29.7)	72.2 (32.1)
Pf CBE	76.5 (63.0)	92.0 (50.7)	109.5 (44.4)	125.5 (44.8)	148.3 (47.7)	110.4 (49.1)
Pf BSR	83.8 (68.9)	104.8 (54.6)	120.3 (52.1)	137.8 (49.4)	160.0 (51.5)	121.3 (53.9)
Pf POL	100.0 (82.3)	121.8 (67.0)	141.5 (61.3)	169.5 (60.5)	191.0 (61.4)	144.8 (64.3)
Distilled Water	121.5	181.8	231.0	280.0	311.0	225.1
(Control)	-	-	-	-	-	-
CD (P=0.05)	4.56	5.08	5.27	4.66	6.34	-

Figures in parenthesis are percentage values

Table 2 Effect of culture filtrate of *P. fluorescens* strain Pf$_1$ on *M. arenaria* mortality

Treatment	Per cent immobile nematodes		Recovery of nematode in distilled water (%)
	At 24 hrs	At 48 hrs	
Culture filtrate at 25% conc.	44.5 (41.8)	50.0 (45.0)	28.0 (31.9)
Culture filtrate at 50% conc.	52.5 (46.4)	58.0 (49.6)	24.6 (29.7)
Culture filtrate at 75% conc.	64.0 (53.1)	67.5 (55.2)	19.3 (26.0)
Culture filtrate at 100% conc.	73.8 (59.2)	78.3 (62.2)	14.3 (22.2)
Autoclaved media broth	18.5 (25.5)	22.5 (28.3)	75.5 (60.3)
Distilled water	0.0 (2.9)	0.0 (2.9)	100.0 (87.1)
CD (P=0.05)	2.4	2.4	1.4

Figures in parenthesis are arc sine transformed values

Table 3 Effect of *P. fluorescens* Pf$_1$ on *M. arenaria* penetration in groundnut

Treatment	Number of nematodes entered into roots (days after inoculation)					
	1	2	3	4	5	6
Pf1	2.0 (2.2)	5.0 (27.8)	12.0 (37.5)	20.0 (36.4)	23.0 (34.3)	25.0 (31.6)
Control	9.0	18.0	32.0	55.0	67.0	79.0
	-	-	-	-	-	-
CD (P=0.05)	1.3	1.8	1.4	2.8	4.7	5.4

Figures in parenthesis are arc sine transformed values

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Short communication

Reaction of sunflower genotypes against rust disease, *Puccinia helianthi* L.

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Sunflower (*Helianthus annuus* L.) is an important oilseed crop in India. It is cultivated in an area of 2.0 m.ha with a production of 0.99 m. tonnes. Yugoslavia records the highest yield of 2031 kg/ha of sunflower against lowest yield of 496 kg/ha in India while the world average being 1242 kg/ha. The rust disease (*Puccinia helianthi*) on sunflower is mainly a foliar disease occurring on almost all parts of sunflower plant. The disease occurs world wide and cause an yield loss of about 35%, apart from reducing the oil content and kernel size (Chattopadhyay, 1998). Sunflower rust completes its entire life cycle on sunflower and can only infect sunflower. The favourable conditions for rust infection are free water on the leaves, either from rainfall or dew, and warm temperatures. A minimum of two hours of wet leaves is sufficient for infection and six to eight hours of leaf wetness will cause the maximum infection of rust. Since chemical control measures are expensive and environmental hazardous, there is a need for the development of rust resistant varieties and hybrids. With this background, inbreds of sunflower grown during *kharif*, 2004 were screened for rust resistance under severe disease pressure.

A total of 663 inbreds were screened for the rust resistance. All the entries were sown on 6th July, 2004 (*kharif*) at Oilseeds Farm, Tamil Nadu Agricultural University, Coimbatore. The inbreds were sown in a 4.2 m row with spacing of 60 x 30 cm. Susceptible variety Morden was sown after every 20 test entries as check. Incidence of rust usually occurs during *rabi* after flowering stage of the crop. However, due to the continuous rain and the resultant high humidity prevailed during the crop growth favoured heavy incidence of rust disease during *kharif* and pre-flowering stage itself. The scoring was done at 50% seed filling stage to enable distinct identification of resistant sources. Based on the intensity of incidence of rust disease, entries were classified into the following category: Morden recorded disease score of 9 and the plants dried even before seed filling stage indicating the severity of the disease to screen for the real resistance source. It is evident from the present study that two inbreds i.e., X 11520-7-1 and X 11007-3-1 showed resistant reaction and 12 inbreds viz., R Sel Bordagen 1, R Sel Bordagen 2, X 11531-1-2, X 11535-1-3, X 11012-3-1, X 11014-20-3, X 11014-20-4, X 11017-17, GP 275, NS 113-1, IH 312-1 and ACC 219 recorded moderate resistant reaction to rust disease.

Leaf area index (%)	Score	Disease reaction
No infection	0	Immune
Less than 1.0	1	Highly resistant
1.0-5.0	3	Resistant
5.1-25	5	Moderately resistant
25.1-50.0	7	Susceptible
More than 50.0	9	Highly susceptible

These inbreds may be utilized in the breeding programme to develop rust resistant hybrid/varieties. Venkara Ramana *et al.* (1995) also reported that CMS 234A and 62A were resistant to rust diseases. Ranganatha *et al.* (2000) reported that, Pet 2 was moderately resistant and CMS 234A as highly resistant. However, in the present study all these entries showed highly susceptible reaction. This indicated the existence of races in these testing locations. Hence, the knowledge on the race pattern of particular location is essential before adopting a resistant variety/hybrid.

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Short communication

Biology of *Spilosoma obliqua* Walker and seasonal incidence of soybean pests

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Soybean is important oilseed and pulse crop. It contains 20% edible oil and 40% protein. It also helps in maintaining soil fertility and fixes atmospheric nitrogen. Due to its proteineous nature and introduction of high yielding varieties, many of the pests started attacking and causing immerse damage to the soybean crop resulting reduction in yield. Considering the extent of damage caused by different pests, several workers found the losses in the yield of soybean to the extent of 37% and infestation to tune of 5 to 78% (Singh *et al.*, 1990). Among various pests of soybean, *Spilosoma obliqua* Walker is the most important pest. Infestation of *S. obliqua* during initial podding of late sown crop resulted in yield losses of about 80%, whereas, infestation at an advanced stage resulted in satisfactory seed development, but a reduction in seed size by about 40 % (Ram *et al.*, 1989). Keeping this in view, the present study was undertaken to study the biology of *S. obliqua* and the seasonal incidence of different soybean pests by correcting them with different ecological conditions so that appropriate control measures can be taken during the right period of time was studied.

An experiment was conducted on soybean crop at the experimental farm of Entomology section, College of Agriculture, Nagpur during *kharif* 2002. An improved variety JS-335 was sown at 30 x 8 cm spacing in 10 x 10 m plot.

Different larval instars of *S. oblique* were collected from the vicinity of soybean fields. The larvae were brought to the laboratory and reared by providing soybean leaves to get the pure culture of pest. The studies on the colour, shape, size and periods of eggs, larva, pupa and adults were undertaken. The pre-oviposition, ovipostion and post-oviposition periods and longevity of adults were also recorded.

The observations on major pests attacking soybean was computed at weekly interval from 7 days after germination to find out the season incidence of major plots.

The eggs of *S. oblique* were spherical and light green in colour and laid in batches on the leaves, but the egg colour changes to black before hatching. Incubation period was ranged from 4.75 to 6.17 days with an average of 5.44 days (Table 1). The larva passed through seven instars. The average body length and width of head capsule of first, second, third, fourth, fifth, sixth and seventh instar larvae were 4.6mm, 8.5mm, 13.1 and 1 mm, 18.5 and 1.3mm, 24.4 and 1.8mm, 29.1 and 2.3 mm and 37.7 and 2.8mm, respectively. The width of first and second instar was not recorded. The total larval period lasted for 25 to 32 days with an average of 28 days. The pupa was dark brown in colour and pupated in soil within 3 - 5 cm layer depth. Larva goes into pupation by spinning a cocoon around its body with silken thread. The average length and width of pupa measured 15.0 mm and 4.6 mm, respectively. The pupa required an average of 12 days to complete development (Table 2). The head of moth was yellowish in colour with dark black compound eyes. The female moths were comparatively bigger in size than males. Antenna was filiform type. The length of body and width of thorax was 19.3 mm and 5.3 mm in female and 15.3 mm and 4.3 mm in male, respectively. The females had shorter life span (5 days) than the males' i.e., 7 days. The female fecundity ranged from 335 to 1280 eggs with an average of 742 eggs/female (Table 1). The above findings were comparable with the observations of Singh and Gangrade (1974). The average pre-mating and mating periods were 15 and 5 hr, respectively (Table 1).

The peak infestation of aphids was noticed in 35th meterological week (MW) (27th Aug. to 2nd Sept., 2002). However, the maximum infestation of leafhoppers and white flies were observed in 33rd (17th to 24th Aug. 2002) and 37th (10th to 16th Sept., 2002), respectively. During peak infestation of these three pests, there was low temperature and high humidity. Chaturvedi *et al.* (1998) observed the outbreak of aphids in the third and fourth week of August. Whereas, Singh and Singh (1991) reported the incidence of leafhoppers from August to September. Bhattacharjee (1986) reported that the white flies thrive well where both temperature and humidity are quite high.

The peak incidence was observed during 35th MW (27th Aug. to 2nd Sept., 2002) in case of tobacco caterpillar and stem fly, however, it was 37th MW (10th to 16th Sept., 2002) in case of green semi-looper, when there was

medium range of temperature and humidity in field condition. Kumar *et al.* (1998) observed the peak period of tobacco caterpillar was around second half of October, while, Singh and Singh (1990) observed the stem fly incidence during second week of August and continue till first week of October. The girdle beetle infestation was seen during later stage of crop growth and maximum infestation of these pests was observed in 37th MW (10th to 16th Sept., 2002). Rai and Patel (1990) observed the infestation of girdle beetle to a level of 0.86 to 12.09%.

From the above finding, it can be concluded that, the total average duration of life cycle of S. obliqua on soybean was 53 days for female and 50 days for male moth during August to October 2002. However, the pests attained their peak periods at the different ecological conditions i.e., from 33rd to 37th meteorological week.

Table 1 Biology of *Spilosoma obliqua* on soybean

Stages	No. observed	Minimum	Maximum	Average
Egg period	-	5	6	5
Larval period	12			
I instar		3	3	3
II instar		4	4	4
III instar		5	6	5
IV instar		5	7	6
V instar		4	5	4
VI instar		3	4	3
VII instar		2	3	2
Total larval period		25	32	28
Pupa (days)	12	11	13	12
Adult period (days)				
Male	7	6	8	7
Female	5	4.8	5	5
Total life period				
Male		-	-	53
Female		-	-	50
Pre-mating period (hr)	5	13	18	15
Mating period (hr)	5	3.3	6	4.6
Fecundity (eggs/female)	5	335	1280	742

Table 2 Seasonal incidence of major pests of soybean during *kharif*, 2002

Met Week (No.)	Date	Leafhoppers	Aphids	Whitefly	Green semilooper	Tobacco caterpillar	Stemfly	Girdle beetle	Rainfall	Rainy days	Temp. (°C)		Relative humidity (%)	
		Av. No./leaf	Av. No./leaf	Av. No./ leaf	No. larvae/ leaf	No. larvae/ leaf	% infestation	% infesta-tion	(mm)	(Actual)	Max.	Min.	Mor.	Eve.
27	6.7.02	1.9	-	-	-	-	-	-	2.5	1	33.3	26.6	66	51
28	13.7.02	2.2	-	-	-	-	-	-	12.7	2	35.3	26.7	61	48
29	20.7.02	2.5	-	-	-	0.6	-	-	56.5	2	31.9	25.5	78	68
30	27.7.02	3.2	2.1	-	-	0.9	-	-	-	-	33.1	25.5	71	49
31	3.8.02	3.8	2.4	2.5	0.4	1.4	-	-	121.8	4	32.8	25.5	81	66
32	10.8.02	4.4	2.9	3.1	0.7	2.5	1.92	-	19.0	2	29.9	24.5	89	72
33	17.8.02	5.9	3.4	3.3	1.2	3.8	3.46	-	83.6	5	27.4	23.3	87	84
34	24.8.02	5.6	4.2	3.8	1.8	5.2	4.61	-	168.0	4	27.8	23.6	88	79
35	31.8.02	5.1	4.6	4.9	2.9	7.0	7.31	1.53	52.8	2	29.8	23.6	80	71
36	7.9.02	4.5	3.9	5.3	4.6	5.7	5.77	4.23	45.1	4	28.5	23.1	81	76
37	14.9.02	3.2	3.4	5.8	6.1	3.8	3.07	6.92	-	-	32.6	23.2	73	51
38	21.9.02	2.7	3.0	4.2	3.2	2.1	2.30	5.00	29.4	1	34.0	22.7	65	45
39	28.9.02	2.1	2.6	3.4	1.4	0.9	1.53	2.69	-	-	35.3	22.5	61	36
40	5.10.02	1.7	1.7	2.3	0.6	-	0.76	1.15	-	-	36.1	20.5	58	30

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Short communication

Antifeedant activity of custard apple, *Annona squamosa* Linn. extracts against castor semilooper, *Achea janata* Linn.

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Botanical pesticides are emerging as environmentally sound alternatives to the synthetic pesticides in view of the adverse effects of the latter to the environment, pest resistance and resurgence. Custard apple (*Annona squamosa*.Linn) is also one of the botanicals, having insecticidal, antifeedant, antitumor and cytotoxic properties (Kawazu *et al.*, 1989). Custard apple seeds and leaf extracts were found effective against *Amsacta moorei* Butler, the hairy caterpillar and these were found effective as that of neem seed extracts under field conditions on groundnut (Patel *et al.*, 1990). Extensive data has been generated on the antifeedant and repellent action of neem extracts (Chari and Muralidharan, 1985; Prakash *et al.*, 1989; Ramachandran *et al.*, 1989), but custard apple received relatively less attention despite the presence of number of antifeedant and insecticidal compounds in the leaves and seeds. In the present study custard apple extracts from leaves, seed powder and seed oil were evaluated in the laboratory against the third instar larvae of castor semilooper for antifeedant activity. Neem kernel extracts and oil were included in the experiment for comparison.

Five types of extracts from leaves, seed powder and seed oil of custard apple and two types from seeds and oil of neem were prepared in water and other solvents few hours before the bioassay (Table 1). The antifeedancy test was carried out by no choice method in 2002. Ten of uniform size third instar castor semilooper (*A. janata*) larvae were tested on treated castor leaves. Castor semi-looper larvae were reared under laboratory conditions with 27±1°C temperature, 70±5% RH and 14:10 light/dark photoperiod. Before treatment, a leaf area meter measured the area of an individual castor leaf. All the botanical extracts were applied in two concentrations i.e., 2.5 and 5.0%. The castor leaves were dipped in respective botanical extracts for one minute and shade dried. The leaf petiole was tied with wet cotton plug to maintain the freshness. Single leaf was placed in an experimental jar containing 10 pre-starved third instar larvae. In each treatment, 10 such jars were maintained and each treatment was replicated three times. A control treatment was also included where leaves were treated with water. The leaf area consumed by an insect was measured after 24h, 48h and 72h of treatment. The leaf area protected in each treatment was estimated and the antifeedant activity of each treatment was calculated (Singg and Pant,1980).

All extracts from custard apple plant exhibited higher antifeedancy compared to the control. The leaf aqueous extract was the least effective (45.9%) at 2.5 % concentration and at 24h with protecting only 64.4% area. Even at 5.0% concentration, the antifeedancy was 67.9%. After 48h and 72h of treatment, this treatment was quiet ineffective. Among other extracts, Annona leaf methanolic extract, showed greater effectiveness. Its activity was as equal to the neem seed kernel aqueous extract. In the leaf extracts, activity rapidly declined due to a possible degradation of the alkaloids. Annona seed oil was the most effective with an antifeedant activity of 100% at 5.0% after 24h of treatment accompanied by significant mortality. The activity was significant even up to 72h of treatment (91.9%). On a comparative basis Annona seed oil was more effective than neem seed oil.

The seed powder aqueous extracts showed intermediate performance between leaf extracts and oil. After 24 h of treatment, there was no significant difference between 2.5 and 5.0 % concentrations (82.1% and 88.8%). However after 48 h. and 72 h of treatment, the differences became significant. In general the methanolic extracts of Annona seed powder showed better performance than the aqueous extracts except in the initial stages, where it was inferior to the water extract.

From this study it can be concluded that Annona crude extracts exhibit significant antifeedant activity against *A.. janata* and the activity was concentration dependent with higher concentrations having much greater antifeedancy with extended incubation. It was also observed that Annona seed oil and seed powder based extracts showed higher effectiveness than foliar extracts. The former were also more stable retaining their activity up to 72h after treatment. These results point to the potential of Annona crude extracts in the integrated management of semi-looper of castor bean and other lepidopteron pests.

Table 1 Antifeedant activity of custard apple extracts against third instar larvae of castor semilooper

Botanical	Concentration (%)	Leaf area protected after 24 h(%)	Antifee - dant activity after24 h (%)	Leaf area protected after 48 h (%)	Antifeedant activity after48h (%)	Leaf area protected after 72 h (%)	Antifeeant activity after72hh (%)
Annona leaf (Aqueous extract).	2.5	64.4 (53.4)	45.9	24.8 (29.8)	7.7	8.9 (17.4)	2.4
	5.0	78.8 (62.6)	67.8	52.0 (46.1)	40.6	16.3 (23.7)	10.3
Annona leaf (Methanolic extract)	2.5	83.07 (69.9)	72.6	65.3 (53.9)	57.1	40.0 (39.2)	35.6
	5.0	90.9 (72.5)	86.2	73.7 (59.2)	67.6	43.82 (41.45)	39.7
Annona seed powder (Aqueous extract)	2.5	88.6 (70.6)	82.1	61.7 (51.8)	52.8	43.3 (41.2)	39.2
	5.0	92.0 (76.5)	88.8	81.1 (64.6)	76.8	72.1 (58.4)	70.2
Annona seed powder (Methanolic extract)	2.5	83.1 (66.8)	75.8	67.3 (55.2)	59.8	58.8 (49.7)	55.8
	5.0	95.2 (77.7)	92.9	80.9 (64.3)	76.4	71.0 (57.6)	68.9
Annona seed oil	2.5	94.0 (78.6)	91.0	69.09 (56.4)	61.7	46.5 (42.9)	42.5
	5.0	100.0 (90.0)	100.0*	97.6 (82.8)	88.7	92.5 (77.1)	91.9
Neem Seed Kernel Aqueous Extract	2.5	81.8 (65.2)	72.1	55.2 (47.9)	44.6	34.8 (36.0)	29.9
	5.0	93.4 (75.3)	89.9	66.7 (54.8)	58.9	46.2 (42.8)	42.2
Neem seed oil	2.5	90.2 (72.3)	85.6	82.0 (65.0)	77.9	74.4 (59.7)	72.6
	5.0	97.7 (82.9)	96.5	96.0 (78.6)	95.1	89.5 (74.6)	88.8
Control	---	33.8 (35.4)	0.00	18.9 (25.7)	0.0	6.7 (14.9)	0.0
Botanical (B)	SEm±	3.0		1.5		2.5	
	CD (P=0.05)	8.8		4.5		7.2	
Concentration ©	SEm±	1.6		0.8		1.3	
	CD (P=0.05)	4.7		2.4		3.8	
B x C	SEm±	4.3		2.2		3.5	
	CD (P=0.05)	NS		6.4		10.2	

Figures in parenthesis are angular transformed values. * = Mortality observed

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Short communication

Economic threshold and management of safflower aphid, *Uroleucon carthami* Hill Ris Lambers

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Among the several stresses, biotic ones have been considered as important factors for low productivity of safflower. A total of 101 pests are known to attack the safflower at different stages of crop growth (Vijay Singh *et al.*, 2000). Among them, aphid (*Uroleucon carthami* H.R.L.) is the major pest of the safflower (Ghorpade *et al.*, 1994) which caused 35 to 72% yield loss during severe infestation (Shetgar *et al.*, 1992), whereas the reduction in oil content of seeds was upto 32% and the seed weight by 50 to 60% (Gautam *et al.*, 1995). Effective chemical control measures have been developed for the aphids (Shetgar *et al.*, 1993; Ghorphade *et al.*, 1994), but the indiscriminate use of insecticides lead to the problems like resistance, resurgence, adverse effects on non-target organisms like predators, parasitoids, pollinators and also residue and environmental pollution. So as to resort to only need based and judicious application of insecticides based on economic thresholds for the pest, the present studies were taken up.

The field experiment was laid out in Randomized Block Design with three replications at Agricultural Research Station, Annigeri to workout economic threshold level of *U. carthami* on safflower variety Annigeri-1 during *rabi*, 1999-2000. The crop was sown during first week of November, 1999 with a spacing of 45 cm x 30 cm between rows and plants, respectively. There were ten treatments each comprising a plot size of 4.0 x 3.6 m. All recommended package of practices except plant protection measures were applied to raise the crop. Economic threshold of safflower aphids was calculated as per Akashe *et al.* (1997).

The applications of dimethoate 30 EC 0.05% were made starting from the first aphid occurrence maintained the required periods of exposure to aphid infestation. T_1 was given complete protection while T_2 to T_9 were given aphid exposure periods of 1, 2, 3, 4, 5, 6, 7 and 8 weeks, respectively followed by complete aphid control throughout the crop. T_{10} was untreated control. The number of sprays required for T_1 to T_9 were 5, 4, 3, 2, 2, 2, 2, 1 and 1, respectively. The observations on the aphid count/5 cm apical twig/plant were recorded on five randomly selected plants from each treatment before each insecticidal application. Finally the seed yield was recorded at harvest.

The data was statistically analysed and economic threshold level was calculated on the basis of number of sprays required, average number of aphids observed and seed yield recorded from different exposure periods to aphids. The gain over untreated control, plant protection cost, monetary returns over untreated control and incremental benefit cost ratios were also taken into consideration.

Study of release and evaluation of predator, *Chrysoperla carnea* against safflower aphid was conducted under field condition. Each treatment was replicated five times in Randomised Block Design with plot size of 2 x 3 m. Treatments imposed were as follows T_1 - *C. carnea* @ one lakh ha in four releases, T_2 - Monocrotophos 36 SL spray @ 0.036%, T_3 - Carbaryl 50 WP spray @ 0.1% and T_4 - *Untreated check. Population of aphid was recorded before* imposing each treatment. At 15 days interval release of *C. carnea* and spray of respective insecticide were made four times. Observations on population of *C. carnea* and aphids were taken on 3rd, 7th and 14th days after each release and spray. The seed yield was recorded at harvest.

The perusal of results revealed that the number of sprays required to maintain given exposures of aphid infestation varied from 1 to 5 (Table 1). Average number of aphids on *5 cm apical twig/plant ranged from 0 to 126 in the* respective exposures of T_1 to T_{10}. The highest number of aphids (126) were noticed in five week exposure period (T_6) followed by period T_5 (100), T_7 (94) and T_8 (75). However, the untreated control recorded an average aphid population of 70.

The yields obtained in all maintained infestation exposures except T_6, T_7, T_8 and T_9 were significantly superior than those obtained in the control (T_{10}). The maximum seed yield of 1362 kg/ha was recorded from complete protection treatment (T_1) followed by T_2 (one week exposure) which produced 1271 kg/ha seed yield. The decreased seed yield was observed to be inversely proportion to exposure time. The same trend was observed in case of increase in yield over control and also with the gain over control. The increase in yield over control ranged between 615 and 122 kg/ha according to the number of sprays given in each treatment.

With regard to the gain over control, it was highest (Rs. 6150/ha) in complete protection followed by one week (Rs. 5240/ha) and two-week exposures (Rs. 3700/ha) to the aphid. The lowest gain of Rs. 1200/ha was obtained in eight week exposure to the aphids with only one insecticidal application. The maximum benefit cost ratio of 6.74 was observed in T_4 (three week exposure), which however, received only two optimum insecticidal sprays. Further, as the exposure period advanced from three to four weeks, the corresponding benefit cost ratios decreased which also received two insecticidal sprays.

Economic threshold level: Economic threshold was calculated following a linear regression model of Y=a+bx for yield versus aphid infestation relationship (Seshu Reddy and Sum, 1991). The values of economic threshold level for two exposure period of aphids (two and three week) were computed (Table 2). Economic threshold for two week exposure was 32, while 46 aphids/5 cm apical twig/plant for three weeks exposure. The mean of these (39) was the economic threshold level. That is about 40 aphids/5 cm apical twig/plant in safflower was the economic threshold level for the exposure periods of two to three weeks from first aphid occurrence. The economic threshold level was found to increase with the decrease in yield and increased aphid exposure increased the economic threshold level.

Population reduction of *U. carthami* aphid: The population reduction of *U. carthami* aphids ranged from 10/plant in monocrotophos to 107/plant in untreated check whereas, *C. camea* and carbaryl recorded population of 94 and 26/plant, respectively after the first release and spray (Table 3).

Table 1 Influence of different periods of aphid infestation on the seed yield of safflower variety, A-1

Treatment	No. of sprays*	Av. No. of aphids on 5 cm apical twig/plant	Seed yield (kg/ha)	Monetary returns above control (Rs/ha)	B:C ratio
T_1 - Complete protection	5	0	1362^{a}	6150	5.04
T_2 - One week exposure followed by complete aphid control	4	25	1271^{ab}	5240	5.37
T_3 - Two week exposure followed by complete aphid control	3	42	1117^{bc}	3700	5.05
T_4 - Three week exposure followed by complete aphid control	2	51	1076^{bc}	3290	6.74
T_5 - Four week exposure followed by complete aphid control	2	99	1016^{c}	2690	5.51
T_6 - Five week exposure followed by complete aphid control	2	126	986^{cd}	2390	4.89
T_7 - Six week exposure followed by complete aphid control	2	94	942^{cd}	1950	3.99
T_8 - Seven week exposure followed by complete aphid control	1	75	890^{cd}	1430	5.85
T_9 - Eight week exposure followed by complete aphid control	1	40	869^{cd}	1220	4.99
T_{10} - Untreated control	0	70	747^{d}	-	-

B:C *ratio = Benefit cost ratio calculated on the basis of monetary returns above control and the cost of insecticide*
Price of produce @ Rs. 1000/q; cost of insecticide @ Rs. 185/l; labour charges @ Rs.90/ha (3 labours/ha/spray)
Figures in the vertical column superscribed by the same alphabet do not significantly differ at 5% level of DMRT
* spray interval = 15 days

Table 2 Economic threshold level (ETL) of safflower aphid

Treatment/exposure	No. of sprays	Av. No. of aphids on 5 cm apical twig/plant	Seed yield (q/ha) (Y)	Y = a+bx	ETL	Mean X
T_3 - Two week exposure followed by complete aphid control throughout the crop	3	42	11.17	11.17= 12.12+(-0.03x)	32	39
T_4 - Three week exposure followed by complete aphid control throughout the crop	2	51	10.76	10.76= 12.12+(-0.03x)	46	

Where, Y = Seed yield obtained (q/ha); a = intercept on Y; b = regression coefficient; x = aphid on 5 cm apical twig/plant

Table 3 **Bioefficacy of insecticides and predator *C. carnea* for the management of safflower aphid**

Treatment	Aphids/plant before treatment	I release/I spray	II release/ II spray	III release/III spray	IV release/IV spray	Yield (kg/ha)
T_1 - *C. carnea*	39	94 (12.2)	119 (21.0)	78 (21.3)	31 (32.5)	817
T_2 - Monocrotophos	41	10 (90.3)	4 (97.7)	3 (97.3)	1 (98.4)	1100
T_3 - Carbaryl	43	26 (75.5)	12 (92.3)	7 (93.1)	2 (95.4)	1050
T_4 - Untreated check	42	107 (0.0)	151 (0.0)	99 (0.0)	46 (0.0)	650
SEm±	1.1	1.8	3.8	2.5	1.4	13.9
CD (P≈0.05)	NS	5.5	11.7	7.5	4.4	42.9

* Population of *U. carthamil*plant (average of 3 observations on 3rd, 7th and 14th day)
Figures in parenthesis are per cent reduction of *U. carthamil*population over check (T_4)

Aphid population was minimum i.e., 4, 3 and 1/plant in monocrotophos sprayed plots whereas, it was 12, 7, 2 and 119, 78 and 31/plant in carbaryl sprayed plot and *C. carnea* treatments and maximum of 150, 99 and 46 in untreated check after 2nd, 3rd and 4th release of *C. carnea* and insecticidal sprays. The average population of *U. carthami* ranged from 4/plant in monocrotophos to 101/plant in untreated check whereas, aphid population of 12 and 80/plant were observed in carbaryl and *C. camea*, respectively. *C. carnea* reduced the aphid population to the tune of 122% over the untreated check after first release. Reduction in aphid population was gradually increased to 21, 22 and 33% after 2nd, 3rd and 4th release, respectively. However, the monocrotophos and carbaryl reduced the aphid population to the tune of 95.7 and 88.4% over untreated check, respectively. The higher rate of *C. carnea* larvae are required to maintain the predator : prey ratio. The yield of safflower ranged from 650 kg/ha in untreated check to 1100 kg/ha in monocrotophos. However, the yield of 1050 and 817 kg/ha were recorded with the treatments, carbaryl and *C. camea*, respectively.

From the present study it may be concluded that the control measures for initial build up of the pest should be taken when the mean aphid infestation level on 5 cm apical twig/plant in safflower is 40 aphids and exposure periods of about two weeks from first aphid occurrence in order to realise a profitable crop. *C. carnea* was found to be highly potential in reducing the aphid population and best suited candidate in integrated pest management programme of safflower aphid (*U. carthami*).

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Short communication

Small green bee-eater, *Merops orientalis* Latham - A potential bird predator on safflower aphid, *Uroleucon carthami* H.R.L.

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Safflower (*Carthamus tinctorious* L.) is an important traditional *rabi* oilseed crop which is attacked by over two dozen of insect pests in India (Singh *et al.*, 2000). Among them safflower aphid (*Uroleucon carthami* H.R.L.) is the most important and key pest which causes considerable yield loss to safflower crop. During *rabi* season of 2000-2001, it was very interesting to note the small green bee-eater (*Merops orientalis* Latham was observed predating in large numbers on safflower aphids in one of the field of All India Coordinated Research Project on Safflower trials laid out on 22-11-2000 at Rajendranagar Farm, Directorate of Oilseeds Research, Hyderabad. This field had an area of 6002.m (30 x 20 m) and was kept unprotected for aphid infestation. The observations were recorded (Table 1) on activity of this predatory bird picking

Table 1 Observations on small green bee-eater predating on safflower aphid

Date	January, 2001						February, 2001					
	Morning (0900-1000 hrs)			Evening (1600-1700 hrs)			Morning (0900-1000 hrs)			Evening (1600-1700 hrs)		
	A	B	Total	A	B	Total	A	B	Total	A	B	Total
1	20	10	30	12	8	20	18	17	35	17	14	31
2	19	10	29	11	8	19	27	18	45	22	6	28
3	31	9	40	25	14	39	15	7	22	11	13	24
4	17	9	26	9	8	17	15	7	22	20	9	29
5	28	8	36	25	14	39	21	9	30	21	10	31
6	31	17	48	22	11	33	24	13	37	14	14	28
7	25	11	36	11	6	17	25	10	35	17	7	24
8	21	12	33	10	8	18	18	13	31	11	8	19
9	28	9	37	9	8	17	27	17	44	19	9	28
10	32	8	40	18	15	33	18	11	29	20	6	26
11	17	12	29	15	14	29	15	7	22	22	13	35
12	15	8	23	24	13	37	17	17	34	16	8	24
13	20	16	36	24	13	37	25	16	41	20	6	26
14	32	14	46	15	14	29	18	18	36	11	10	21
15	29	17	46	18	8	26	18	13	31	11	9	20
16	21	11	32	10	8	18	15	17	32	20	14	34
17	28	10	38	11	8	19	24	7	31	13	7	20
18	20	12	32	23	14	37	27	16	43	16	10	26
19	17	8	25	9	5	14	21	11	32	21	6	27
20	30	9	39	13	11	24	19	10	29	11	13	24
21	13	14	27	25	15	40	15	7	22	20	8	28
22	28	17	45	15	8	23	25	18	43	22	10	32
23	32	13	45	23	12	35	20	16	36	15	7	22
24	30	8	38	10	5	15	15	7	22	20	14	34
25	26	14	40	11	6	17	16	10	26	11	6	7
26	31	16	47	14	7	21	17	13	30	11	13	24
27	13	11	24	9	11	20	27	11	38	22	9	31
28	28	13	41	23	12	35	16	10	26	17	14	31
29	26	8	34	11	5	16						
30	17	17	34	10	5	15						
31	30	9	39	22	11	33						
* Range	13-32	7-18	22-48	9-25	5-15	14-40;	Average:	22	12	34	16	10	26

* The figures of range and average are calculated on per day for two months; A = No. of birds picking aphids; B = No. of birds resting on wire

aphids from this unprotected field and sitting/resting on telegraphic wires near the observational field in the morning 0900 to1000 hrs and in the evenings 1600 to 1700 hrs daily for two months i.e., January and February, 2001. The aphid incidence was quite high ranging from 90 to120 aphids/5cm central twig/plant.

The bird is green coloured and small in size, reddish brown on head and neck, long central tail-pins, long slender, slightly curved bill, pale blue on chin and throat, bordered below by black gorged and sexes alike. It is distributed through out India and about 100 m above sea level in the Himalayas, resident and locally migratory (Salim Ali, 1996). Its habit is to often associate in small loose parties of about 15-20 birds or more. These birds sit on perches in the fields, small trees, dead branch posts, telegraphic wires and some times on the back of cattle, along with drongos, cattle egrets and mynahs. They launch aerial rallies after winged insects. They fly with a few rapid flaps followed by graceful swallow like glides. Their habitat is the open country side and cultivated areas and light forests. They feed on Hymenopteran insects like ants, bees and wasps. They are reported to be nuisance to the honey industry as they are good feeder of honey bees. Studies conducted by All India Network Project on Agricultural Ornithology, Ludhiana revealed that the diet of this bird constituted by weight, Hymenoptera (81%), Odonata (11.6%), Diptera (2.4%), Lepidoptera (1.8%), Orthoptera (1.3%), Coleoptera (1%) and others (0.9%) (Salim Ali, 1996; Anonymous, 2002).

Predation by *M. orientalis* on safflower aphid: Number of bird picking aphids was higher (average 13-32 birds in the morning and 9-25 birds in the evening) per 600^2.m than the birds sitting/resting on telegraphic wire (average 7-18 birds in the morning and 5-15 birds in the evening). Predation activity of bird on aphids/day in the field was more (34 birds) in the morning and low (26 birds) in the evening (Table 1). It is the first record in India that this bird was found predating on Homopteran insects (aphids). This bird may be used as a tool of IPM in safflower by erecting bird perches in the fields.

It was concluded that the predation on aphids by small green bee-eater (*Merops orientalis* Latham) is the first record in India. The bird reduced the aphid population drastically in safflower crop and was useful as a natural component of IPM in safflower.

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Short communication

Growth and instability of groundnut, *Arachis hypogaea* production in Orissa

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Orissa ranks seventh position in groundnut production in the country. It occupies 1.1% of the groundnut area and 0.8% of production at national level. Wide fluctuations in production of groundnut are witnessed year to year in the state which adversely affect the income distribution of the groundnut growing farmers and in turn slows down the process of agricultural development of the state. For a planned reorientation of production strategy, it is necessary to know about the rate of growth of groundnut output and its instability.

Keeping the above points in view, the present study was taken up to analyse the growth and instability in groundnut in Orissa by using decomposition technique developed by Hazel (1982 and 1984).

The time series data pertaining to area, yield and production of groundnut for a period of 30 years (1969-1979 to 1999-2000) were collected and analysed by dividing the whole period into three decades *viz.*, decade-I (1969-70 to 1979-80), decade-II (1979-80 to 1989-90) and decade-III (1989-90 to 1999-2000). The statistical methods used in the study are explained as follows:

Growth model: A widely accepted growth model i.e., Y = ab'e^{u} has been fitted to the time series data for estimating growth rates, whose log linear equation of the fitted model is given by ln(y) = ln(a)+t ln(b)+u

Where, 'y' is the per hectare yield/area/production of groundnut, 't' is the time period, 'u' is the disturbance or *error term, a and b are the parameters to be estimated* from the sample observation. The regression coefficient 'b' was computed by ordinary least Square (OLS) technique.

The compound growth rates (CGR) were estimated as:

CGR (in per cent per annum) = (antilog b-l) x 100

Coefficient of variation (CV) and its test of significance

Instability in groundnut production is measured with coefficient of variation for three decades which is given by

$$C.V. = \frac{\sigma}{\bar{X}} x 100$$

Where, 'σ' is the standard deviation of groundnut production $\bar{x}$ is the average production of groundnut.

To test the significance of C.V., the test static 't' is used which is given by:

$$t = \frac{C.V.}{S.E.(C.V.)}, \text{ with (n-2) d.f.}$$

$$\text{Where, } S.E.(C.V.) = \frac{C.V}{(2n)^{1/2}} x \left[1 - \frac{2x(C.V)^2}{10^4}\right]^{1/2}$$

Instability in groundnut production is also measured by change in mean production variance with respect to the base period by using decomposition technique.

Decomposition of mean production: The change in average production $\Delta E(p)$, between the decades is decomposed into sources of changes which is given by

$$\Delta E(P) = \Delta \bar{A} + \Delta \bar{Y} + \Delta \bar{A}.\Delta \bar{Y} + \Delta \bar{C}ov(A,Y)$$

Where, $\Delta \bar{Y}$ = Change in mean yield

$\Delta \bar{A}$ = Change in mean area

$\Delta \bar{A}.\Delta \bar{Y}$ = Interaction between change in mean area and mean yield

$\Delta \bar{C}ov(A,Y)$ = Change in area - yield covariance

Decomposition of variance of production

Following the works of Goodman (1960), the variance of production can be expressed as:

$$V(P) = \bar{A}^2 V(Y) + \bar{Y}^2 V(A) + 2\bar{A}.\bar{Y} + Cov(A,Y) - Cov(A,Y)^2 + R$$

Where, $V(P)$ = Variance of production

$V(Y)$ = Variance of yield

$V(A)$ = Variance of area

$Cov(A,Y)$ = Covariance of area and yield

The change in variance of production $\Delta V(P)$ between decades can be decomposed into ten sources of change *viz.*, change in mean yield $(\Delta \bar{Y})$, change in mean area $(\Delta \bar{A})$, change in area-yield covariance $[\Delta Cov(A,Y)]$, change in yield variance $[\Delta V(Y)]$, change in area variance

$[\Delta V(A)]$, interaction between change in mean area and yield variance $[\Delta \bar{A} \Delta V(Y)]$, interaction between changes in mean yield and area variance $[\Delta \bar{Y} \Delta V(A)]$, interaction between changes in mean yield and changes in area-yield covariance, and changes in residuals ((ΔR).

The results of the study are discussed under two heads *viz.*, growth and instability analysis.

Growth rate analysis

The decade-wise compound growth rates of area, yield and production of groundnut are presented in Table 1. Growth rate analysis from Table 1 reveals that over the period of 30 years, the area under groundnut increased significantly at the rate of 4.26%. The highly significant increase in growth rate of output was 7.31% due to increase in growth rate of both the area and yield. Decade-wise growth rates showed that during first decade both the area and yield increased significantly at the rate of 8.05% and 4.99%, respectively. Similarly, during the second decade the growth rate of area and yield found to be 10.05% and 5.31%, respectively. During the third decade the growth rate increased to 11.45% and 5.25% for area and yield respectively.

Table 1 Decadewise compound growth rate of area, yield and production of groundnut in Orissa

Decade	Area	Yield	Production
I	8.05**	4.99**	8.20**
II	10.05**	5.31**	10.79**
III	11.45**	5.23**	11.94**
Whole period	7.85**	4.26**	7.31**

** Significant at 1% level of probability.

Instability analysis

The most commonly used statistical relative measure such as coefficient of variation (CV) has been considered for studying the instability of groundnut production in Orissa. The estimated decade-wise change in average production and CV of groundnut production along with test of significance are presented in Table 2.

Table 2 Decadewise changes in average and CV of groundnut production in Orissa

Item	*Decade*			*Per cent change*		
	I	II	III	I-II	I-III	II-III
Average production ('000 MT)	250.20	342.20	377.30	36.77	36.80	10.25
CV	20.87**	22.64**	30.64**	8.45	46.79	35.36
t-value of CV	10.58	15.92	18.50	-	-	-

** Significant at 1% level of probability

The groundnut production of Orissa was increased by 36.8% during third decade over first decade and the same was observed in other period also. The CV in production was more during third decade (30.64%) as compared to first (20.87%) and second decade (22.64%). Again it is concluded from the test of significance of CV that the variability of groundnut production in Orissa was highly significant at 1% level of probability indicating more or less existence of instability in groundnut production.

The changes in CV of production over the decades depend upon the changes in mean and variance of production. Therefore, it is important to further probe into the sources of changes in mean and variance of production.

Sources of changes in mean production of groundnut in Orissa: The results of the decomposition of the changes in average production of groundnut in Orissa are presented in Table 3.

The average production of groundnut in the state increased by 10.25% in the third decade (Table 2) from 342.20 ('000 MTS) in 1989-1990 to 377.30 ('000 MTs) in 1999-2000. It is apparent from the analysis that out of 10.25% increase in production during third decade over second decade, the contribution of change in mean yield, change in area - yield covariance and interaction between changes in mean area and mean yield were 1.77, 20.49 and 96.59%, respectively whereas, the contribution of change in mean area was (-) 18.85% towards the change in production. It concludes that over all the decades under study, mean area effect had negative contribution (-18.85%) during third over second decades indicating the less importance in coverage of area under groundnut cultivation. Considering the contribution of yield effect on the change in mean groundnut production over all the decades, the yield contributed highest per cent of 42.74% during (I-II) decades followed by 18.63% during (I-III) decades.

Sources of changes in variance of groundnut production in Orissa: A decade-wise summary of component of changes in variance of groundnut production in Orissa is presented in Table 4. It could be seen from Table 4 that instability in groundnut production during third decade was attributable to changes in mean yield (11.43%), mean area (28.04%), interaction between changes in mean area and mean yield (7.59%), area variance (16.67%) and interaction between changes in mean yield and area variance (15.49%). However, changes in yield variance (-23.03%), area-yield covariance (-127.24%) and interaction between changes in mean area and yield variance (-11.54%) were responsible to stabilize groundnut production in Orissa.

Table 3 Components of changes in mean groundnut production in Orissa

Components change (%)	Decades		
	I-II	I-III	II-III
Mean area	26.56	65.47	-18.85
Mean yield	42.74	18.63	1.77
Area-yield covariance	9.84	-3.35	20.49
Interaction between changes in mean area and mean yield	20.86	19.25	96.59

** Significant at 1% level of probability

Table 4 **Decade-wise components of changes in variance of groundnut production in Orissa**

Components change (%)	Decades		
	I-II	I-III	II-III
Change in mean yield	30.65	37.05	11.43
Change in mean area	27.99	42.16	28.04
Interaction between change in mean area and mean yield	14.68	16.60	7.59
Change in area-yield covariance	-114.87	39.46	-127.24
Change in yield variance	41.67	16.89	-23.03
Change in area variance	139.50	22.35	16.67
Interaction between change in mean area and yield variance	18.02	-37.21	-11.54
Interaction between changes in mean yield and area variance	22.75	36.59	15.49
Interaction between changes in mean area and mean yield and changes in are-yield covariance	-95.11	-42.65	-57.87
Change in residuals	14.72	-31.24	-6.32

** Significant at 1% level of probability

Conclusion: The total groundnut production of Orissa has increased by 36.8% and 10.25% per annum during third over second and first decade, respectively. The instability of production is more in third decade than first and second decades. The change in mean production of this crop is mainly due to three components i.e., area, yield and area-yield covariance effect. On variability point of view, out of ten contributing components, four components *viz.*, changes in mean yield, changes in mean area, interaction between changes in mean area and mean yield, changes in area variance are important towards the change in production variance. The results of the study indicate that area is the dominating source of output growth of groundnut in the state. As area expansion has limited scope, efforts to increase per hectare yield will be major thrust in increasing groundnut production in the state in future.

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Short communication

Transfer of improved technology through frontline demonstrations in groundnut, *Arachis hypogaea* L.

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Gujarat is one of the main groundnut producing states of India, with an acreage of 20 lakh ha which is mostly grown under *kharif* and confined to Saurashtra and Kutch regions. The frontline demonstrations (FLDs) conducted from 1995 - 96 through 2003 - 04 in four middle Gujarat districts, *viz.*, Kheda, Panchmahals, Vadodara and Anand, where the Summer groundnut cultivation is practiced after *Kharif* paddy was considered for the study. In order to transfer to the improved technology of groundnut the frontline demonstrations were conducted across years under real farm situations of middle Gujarat for assessing the potential yield between improved and farmers practice and yield gaps. The whole package approach demonstrated to the farmers through FLD trials included the components like improved varieties, seed rate, spacing, irrigation, fertilizer and plant protection measures. The data generated, both in whole package and component technologies were utilized for calculating the technology index, technology and extension gaps using *the following formulae*:

(I) Technology gap: (Potential yield) - (Demonstration yield.)

(ii) Extension gap: (Demonstration yield) - (Farmers yield)

(iii) Technology Index: (Technology gap/Potential yield) x 100

The study revealed that the improved technology (IT) registered pod yield increase ranging from 6.00 to 32.9 % over the farmers practice (FP). The average yield ranged between 1632 to 2509 kg /ha and 1285 to 1888 kg/ha in IT and FP plots respectively (Table.1). Over the years there *was no marked variation among the mean yields both in IT* and FP plots as was evident from the low cv. However, the yield of IT plot exceeded that of FP plots across the years. This was attributed due to the quality seed used, adequate seed rate, judicious use of fertilizers and irrigation. Similar results were reported by Suryavanshi and Mahendra Prakash (1993).

The data further revealed that the technological gap existed between the potential and demonstrable yields was not substantial indicating that the results obtained in research experiments were also replicated under real farm situations also as seen from FLDs. The gap existed between 0 to 368 kg/ha across the years except during 1995-96 where it was negative (- 509 kg / ha). In case of *the extension gap it ranged to the tune of 114 to 621* kg/ha. It can be inferred that the extension gap can be mitigated by adopting improved varieties and other management practices of groundnut cultivation.

The technology index varied from 0 to 25.5% during all the years, which gave evidence that there is still further scope for improvement and enhancing the productivity of groundnut. Similar findings were also reported by Kadian *et al.* (1997) and Thakral and Bhatnagar (2002). The *economics of the improved technology revealed that* during all the years except 1997-98 and 2003-04 the production cost of FLD was higher than the local practices (Table 2).

Table 1 Impact of improved technologies on the productivity potential of groundnut variety GG-2

Year*	No. of FLD	Mean yield** (kg/ha)		Range (kg/ha)		Mean yield increase over FP (%)	Technological gap (kg/ha)	Extension gap (kg/ha)	Technology index (%)
		IT	FP	IT	FP				
1995-96	15	2509	1888	1000-4210	800-2850	32.9	(-) 509	621	25.5
1996-97	15	1688	1471	1410-1975	1310-1690	14.8	312	217	15.6
1997-98	13	1710	1555	600-2500	590-2300	10.0	290	155	14.5
2001-02	10	1660	1335	1000-2500	900-1750	24.3	340	325	0.2
2002-03	10	2000	1886	1500-3200	1400-3000	6.0	0	114	0.0
2003-04	10	1632	1285	1000-2225	750-1750	27.0	368	347	18.4
Mean		1867	1570	600-4210	590-3000	19.2	134	297	12.4
CV (%)		9.90	10.57						

* FLD not conducted during the years, 1998-2001; ** = IT : Improved technology; FP : Farmer's practice

The stalk yield in castor was also significantly higher in sole crop . Minimum stalk yield was found in combination having castor + unpollarded trees. The increase in stalk yields could be mainly attributed to increased dry matter production. These results are in accordance with the findings Madhusudhan (1997).Harvest index did not differ significantly .

Economics: Benefit cost ratio of the system was considerably influenced by cropping situations with integrated nutrient management practices. The higher benefit cost ratio from the system (Tree +crop) was obtained in intercropping of castor under pollarded trees (1.76). Where as the benefit castration from the system was found more or less same both under intercropping of castor in unpollarded trees (1.36) as well as sole cropping of castor (1.38). Among the different nutrient management practices studied , application of 150% of recommended dose of nitrogen either alone (1.6) or combined with mulch (1.6) recorded highest values of benefit cost ratio from the system, this was followed by recommended dose of nitrogen combined with FYM (1.5) or mulch+FYM (1.5).The results are in line with the findings of Subrahmanyam *et al.* (2001).

Table 1 Effect of different cropping situations and integrated nutrient management practices on castor yield attributes, seed and stalk yields, harvest index and benefit cost ratio from the system

Treatment	Number of spikes/plant	Number of capsules/ spike	Test weight (g)	Seed yield (kg/ha)	Stalk yield (kg/ ha)	Harvest index (%)	B:C ratio
Cropping situations							
Intercropping of castor in unpollarded trees (IC)	2	15	16.4	226	736	23.3	1.4
Intercropping of castor in pollarded trees (ICP)	3	31	20.7	471	1534	23.3	1.8
Sole cropping of castor (SC)	3	37	21.5	602	2151	21.8	1.4
SEm±	0.1	0.4	0.2	4.0	19.4	0.4	-
CD (P=0.05)	0.2	1.1	0.4	11.2	53.8	NS	-
Integrated nutrient management practices							
Recommended dose of nitrogen	1	23	17.4	330	1299	20.8	1.4
Recommended dose of nitrogen + FYM	2	25	19.0	434	1483	22.8	1.5
Recommended dose of nitrogen + mulch	2	25	18.5	389	1421	21.8	1.4
Recommended dose of nitrogen + mulch + FYM	3	31	21.0	463	1485	23.8	1.5
150% of recommended dose of nitrogen	3	31	20.30	471	1512	23.8	1.6
150% of recommended dose of nitrogen + mulch	4	32	20.89	511	1641	23.9	1.6
SEm±	0.1	0.6	0.2	5.8	22.3	0.4	-
CD (P=0.05)	0.2	1.3	0.4	11.9	45.5	0.8	-

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Short communication

Variation in morphological and biochemical components of neem, *Azadirachta indica* A. Juss seeds from Haryana

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Neem (*Azadirachta indica* A. Juss) products have a great potential in solving several agricultural and public health problems. Azadirachtin, the principal limonoid of neem seeds has attracted tremendous attention because of its potential to replace the toxic pesticides with a safe and sustainable home grown alternative. Neem is considered to possess greater variability compared to other tropical tree species (Bisla and Beniwal, 1997). Therefore, the present study was carried out to identify individual tree with high oil and azadirachtin content which can be utilized for plantation and genetic improvement programmes.

Mature fruits of neem were collected from 15 individual plus trees from different locations around Hisar (29°10 N latitude, 75°46 E longitude, 215 m altitude), Haryana during 2004-05. The climate is sub-tropical monsoonic with an average annual rainfall of 350-400 mm, 70-80 % of which occurs during July to September. The minimum and maximum temperature varies from 0°C during winter to 48°C during summer. Plus trees (PT) were selected based on phenotypic assessment of characters of economic interest. Collected neem seeds were depulped and washed and air dried at room temperature for 5-6 days. Thereafter, observations were recorded on seed morphological and biochemical parameters. Oil and fatty acid composition of individual tree seed samples were estimated by nuclear magnetic resonance (Medsen, 1976) and gas liquid chromatography (Flotch *et al.*, 1957). *Azadirachtin* content of seeds was measured using HPLC technique.

Among the selected plus trees, seed length ranged between 1.0 and 1.5 cm with an average of 1.2 cm. The maximum seed width (0.7 cm) was recorded in seeds of plus tree PT-11 closely followed by PT-8. The 100-seed weight varied from 13g (PT-5) to 25g (PT-11). Plus trees PT-1, PT-2, PT-6, PT-9, PT-11 and PT-12 had significantly higher 100-seed weight than general mean. Earlier, several research workers also reported intra and inter provenance variation in seed morphological characters of neem (Kaura *et al.*, 1998; Kulkarni *et al.*, 2000). They pointed out that seeds with less weight were mostly from dry areas. Seed size was found to be directly proportional to seed weight. Oil content values varied significantly ($P<0.05$) among the selected plus trees, oil content ranged from 39 in PT-13 to 49% in PT-3. Surendran *et al.* (1993) also reported a variation in oil content of neem (41.9 to 46.9%) collected from Dharampuri, Tamil Nadu. *Azadirachtin* content also showed statistically significant variation in seeds of selected plus trees. It ranged from 0.8 mg/g (PT-5) to 6.2 mg/g (PT-7), with an average of 2.1 mg/g. Plus trees PT-6, PT-7, PT-9 and PT-10 contained significantly higher azadirachtin than general mean. With the increasing interest in *azadirachtin*, as a source of botanical pesticide, several researchers collected germplasm of neem from diverse eco-geographical regions of India and reported that neem ecotypes vary widely in their *azadirachtin* content (Rengaswamy and Parmar, 1995; Sidhu *et al.*, 2003). Neem oil was devoid of erucic and linolenic acid in all samples studied but rich in palmitic (15.9 to 22.4%), stearic (2.1 to 17.7%), oleic (47.5 to 68.0%) and linoleic (7.9 to 17.9%) fatty acids. Interestingly, the fatty acids also showed significant differences among the selected trees (Table 1). The above findings are in close agreement with those reported by Kumar and Parmar (1997) and Kaushik and Vir (2000) in neem. Seed length, width and 100-seed weight had significant positive correlation with palmitic acid (Table 2) of neem seeds collected from neem fruits. Jindal *et al.* (1999) also reported similar results in neem seeds.

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Table 1 Morphological characters and biochemical composition of neem seed

Plus tree	Seed length (cm)	Seed width (cm)	100-seed weight (g)	Oil content (%)	*Azadirachtin* content (mg/g)	Fatty acids (%)			
						Palmitic	Stearic	Oleic	Linoleic
PT-1	1.5	0.6	23	41	1.9	19.7	2.1	67.9	7.9
PT-2	1.4	0.7	22	38	1.7	22.4	3.9	54.1	13.8
PT-3	1.3	0.6	18	49	1.1	17.6	5.2	65.4	7.9
PT-4	1.1	0.6	17	40	2.3	16.3	4.5	65.8	11.0
PT-5	1.0	0.6	13	42	0.8	18.6	3.6	58.6	13.8
PT-6	1.2	0.6	21	44	3.5	20.6	8.1	51.2	15.0
PT-7	1.3	0.6	19	42	6.2	19.6	2.7	61.7	13.0
PT-8	1.3	0.7	17	40	1.5	19.2	6.1	49.9	14.3
PT-9	1.3	0.6	23	44	2.6	19.9	2.2	62.2	12.0
PT-10	1.2	0.6	16	46	4.4	15.9	3.2	60.4	17.9
PT-11	1.4	0.7	25	46	1.0	22.1	11.1	47.5	15.9
PT-12	1.4	0.7	22	42	1.6	18.3	3.0	62.0	14.3
PT-13	1.2	0.6	17	39	0.9	20.5	5.2	60.0	11.9
PT-14	1.3	0.6	20	42	1.0	19.8	17.7	49.6	9.6
PT-15	1.0	0.6	15	42	1.5	16.5	2.5	65.5	10.1
Mean	1.2	0.6	19.2	42.6	2.1	19.1	5.4	58.8	12.6
CD (P = 0.05)	0.1	0.1	1.0	2.4	0.3	0.7	0.9	3.2	1.1

Table 2 Correlation coefficient among seed morphological and bio-chemical characters in neem

Character	Seed length	Seed width	100-seed weight	Oil content	*Azadirachtin* content	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid
Seed length	-	0.805**	0.775**	-0.041	-0.093	0.547*	0.171	-0.225	-0.060
Seed width		-	0.596*	-0.180	-0.258	0.646**	0.341*	-0.507*	0.072
100-seed weight			-	0.101	0.003	0.628**	0.185	-0.212	0.002
Oil content				-	0.071	-0.165	0.198	-0.037	0.097
Azadirachtin content					-	-0.160	-0.310	0.166	0.327
Palmitic acid						-	0.343*	-0.606**	0.129
Stearic acid							-	-0.729**	-0.020
Oleic acid								-	-0.514*

*,** Significant at 5 and 1% levels

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INDIAN SOCIETY OF OILSEEDS RESEARCH
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National Seminar
"Changing Global Vegetable Oils Scenario - Issues and Challenges before India"

January 29-31, 2007 Hyderabad

FINAL RECOMMENDATIONS

India has the fourth largest vegetable oil economy in the world next only to USA, China and Brazil donning the role of oilseeds grower, producer, exporter and importer. The Indian oilseed scenario witnessed changes in the recent past wherein the country transformed from a net importer in the early 1980's to net exporter in the early 90's. The country reverted back as net importer from the late 90's with imports hovering around 40-53 % of the annual edible oil requirement. This reversal is attributed to a gamut of factors *viz.*, shortage of oilseeds in domestic supply chain due to biotic and abiotic stresses that beset cultivation, sustained increase in consumption of edible and non edible oils and the lack of competitiveness to cope up with changes /reforms at the global level. The production and processing efficiency of oilseeds in India is around 40 and 90% less than in China and USA while the technical inefficiency ranges from 50-65%. Despite production of 27.9 million tonnes of oilseeds during 2005-06, the country was forced to import around Rs. 9,000 crores worth of vegetable oils to bridge the demand-supply gap. Being income-elastic the demand projections of vegetable oilseeds by 2010 is 44 million tonnes with a conservative 3-4% annual increase in demand for oils. Hence a holistic approach for revitalizing the domestic edible oilseed sector is warranted to safeguard the national interest to bridge the huge drain on imports and to instill a high level of confidence in the oilseed growers for furtherance of the productivity. This is expected to bolster the supply chain mechanism which in turn increases the efficiencies at both production and processing levels.

It is against this backdrop that the National Seminar entitled "Changing Indian Vegetable Oils Scenario: Issues and Challenges before India" was organized by the Indian Society of Oilseeds Research (ISOR) at Hyderabad during 29-31 January 2007. The seminar deliberated on key issues *viz.*, Integrated resource management, Vegetable oils as biofuels, Current trends in pest management, Policy frame work for oilseed sector, Genetic diversity and gene mining, Post harvest management and processing, Information and transfer of technology and Non-conventional vegetable oils. Intensive discussions and seminal deliberations held during the seminar culminated in the following recommendations:

1. Since high levels of technical inefficiencies are predominant in the production front because of uncertain rainfall, low input agriculture and small holdings, well organized contract farming has to be taken up on a massive scale in oilseed production for harnessing the economies of scale thus resulting in enhanced production and income. Public-private partnership that will be mutually beneficial should be exploited.

2. Intensification in the oilseed sector is possible through provision of some incentives like production subsidy as well as market intervention with remunerative price to the oilseed growers. This can act as a catalyst for greater area allocation and more intensified efforts. Since oilseeds require limited quantity of irrigation as against the normal irrigated crops, incentives will enthuse the farmer to opt for oil seed crops.

3. De-reservation of traditional oilseeds (groundnut, rapeseed-mustard, sesame, safflower, castor) from the small scale processing by promoting large scale processing units operational at a scale comparable to world's standards (1200-1500 tonnes/day) can increase the processing efficiency benefiting both oilseed producers and consumers. A strong producer-processor linkage mechanism is warranted for input, marketing and, regular supply chain with accrued benefits to both the producer and processor.

4. A balanced tariff structure/ import duty reforms should be put in place keeping the interest of the consumer, domestic oilseed production and the internal price mechanism in the vegetable oil sector for pegging down the inflation rate.

5. Keeping in view the international vegetable oil prices, subsidies and the domestic input costs, production subsidy and market intervention for output marketing can play a key role in diversification in favour of oilseed crops.

6. Oilseeds production continues to depend predominantly on monsoon resulting in low and uncertain yields. There is a need for greater thrust on drought proofing of oilseeds production through soil and moisture conservation and crop management technologies and timely weather forecasting.

7. Greater emphasis on mechanization of oilseeds cultivation and post harvest operations is the need of the hour for ensuring efficiency and timely operations.

8. Declining total factor productivity and low use efficiency of agro-inputs (nutrients, plant protection chemicals and water) is making oilseeds production less profitable. This calls for adoption of site-specific crop management on cropping system basis, for increased input use efficiency, higher productivity and profitability.

9. Organic agriculture needs to be encouraged in identified special niches for crops like niger, sesame, HPS groundnut, safflower for dual purpose (petals and seeds), etc., that have high export/direct consumption value.

10. Concerted efforts are to be made urgently in expansion of oil palm in the potential regions for augmenting the domestic production so that the country can reap substantial production of 3-4 million tonnes of palm oil in the next two decades. This warrants setting up of oil palm board, encourage captive plantations, provision of credit support to the farmers besides making available quality planting material. The above steps could significantly boost the Indian oilseed economy and also insulate to a great extent the impact of weather dependent fluctuations in annual oilseeds production.

11. The enormous potential of rice-bran and cotton seed is to be exploited for supplementing the domestic vegetable oil supply. As against the potential 14 lakh tonnes of rice-bran oil that could be tapped, at present only 7.0 to 7.5 lakh tones of oil is harnessed thus indicating the potential for doubling of rice-bran oil production, if fully exploited. Similarly, given the availability of enormous quantity of cotton-seed, there lays immense scope for exploiting the cotton seed oil through scientific processing for increased oil recovery. The non-conventional oilseeds from both annual and perennial sources (tree-borne oilseeds) could be exploited for augmenting the domestic oil production which in turn can help in reducing the import of vegetable oils.

12. There is an urgent need for promoting and popularizing biological control of oilseed pests by ensuring availability of proven biocontrol agents like Bt, NPV, *Trichoderma* spp., *Pseudomonas* spp., and entomopathogenic fungi (*Metarhizium anisopliae, Beauveria bassiana*, *Verticillium lecanii etc.*,) through development of suitable mass production and delivery mechanisms and their effective integration into IPM modules.

13. In India, several vegetable oilseed crops have been identified, the seed oils of which can be esterified to manufacture bio-diesel. However, inspite of its huge potential, information related to the region-specific appropriate cultivation practices, good seed material, and economics of its cultivation is lacking. Hence, it is essential to undertake in-depth research on:

    - Systematic collection and evaluation of germplasm to identify elite planting material and its mass multiplication.

    - Agronomic studies to standardize cultivation practices such as spacing, nutrition, pruning methodology and production system under different agro-ecological conditions to enhance seed and oil yield.

    - Research on the variability of feed stocks and possibility of usage of different feed stocks, esterification process and the development of designer engines to suit to the feed stock have to be considered.

14. There is a need for effective harnessing of enormous genetic potential existing in the country for broadening the variability in breeding material. Major emphasis is needed on explorations for collection of diverse material from regions of diversity, target oriented collection and gene mode conservation of genetic resources, integration of multi location evaluation and utilization of molecular markers for development of core collection and pre-breeding for genetic enhancement.

15. The focus of oilseed crop breeding research need a paradigm shift from increased production to increased production with efficiency with increased economic returns. There is a need for trait-based population development for crops where varieties play an important role and heterosis-based population development for hybrid development in crops like sunflower, rapeseed-mustard, castor and safflower. Conventional breeding and biotechnological tools need to be integrated for genetic manipulation of oilseed crops and as a prelude genotype-independent transformation protocols have to be developed for all oilseed crops. There is also urgency for development of appropriate mapping populations and identification of molecular markers and MAS for enhancing the efficiency of the resistance breeding programmes. Breeding researches till date have focused on development of oilseed varieties with increased oil content. On the international front, the plasticity of the fatty acid biosynthesis pathway and the tolerance of oilseed crops to metabolic manipulations have been successfully exploited for incorporation of additional fatty acids of nutritional and industrial importance from heterologous systems, low cost production of industrial fatty acids and also in over expression or down regulation of single gene to tinker fatty acid biosynthetic pathways for obtaining desired fatty acid profiles. With the growing awareness for nutritionally enhanced edible oils among consumers, there is an immediate need for initiating genetic engineering for modification of oil and development of designer oils tailor made for nutritional and industrial needs.

16. The scale of oil production was less than optimum by the processing units to the extent of 91 to 98 %. Therefore, considerable scope exists in improving the productivity and profitability of oilseed processing units through better capacity utilization (*i.e.*, modern and efficient processors) and improved turn over.

17. Vegetable oil industry has to very actively consider the possibilities of value addition to the byproducts obtained during the processing of oils in view of their high price in domestic and international markets and to increase the total profitability of oilseed sector which in turn will increase the competitiveness of the oilseed crops. Thus research initiatives in this area are of paramount importance.

18. In most of the oilseed crops, lack of strong need based seed multiplication at foundation and certified stages, in spite of sufficient breeder seed production, is the key constraint in availability of quality seed material. The present level of seed replacement ratio for oilseed sector as a whole is 6-8 % whereas for major oilseed crops like groundnut and soybean, it is just 2 and 6 % respectively. Integration of seed enterprises and farm managed seed systems through "seed village" programme wherein oilseed growers have a key role to play in seed production through participatory mode is an effective mechanism to produce quality seed material and make it available to farmers. This type of seed production coupled with a marketing tie up with seed selling agencies would ensure quality seed production and distribution. This concept needs to be replicated at national level under appropriate policy framework to augment quality seed supply.

19. Lack of availability of much needed services *viz.*, knowledge on improved agro-techniques and information as well as linkage to market infrastructure to oilseed growers, warrants an effective model of transfer of technology to improve the oilseed production scenario. The "e-Choupal" model successfully facilitated the oilseed growers with services *viz.*, accessibility to customized knowledge on scientific cultivation, procurement of produce and linkage to remunerative market network. Hence, there is a need to replicate this model, under an appropriate policy framework which provides an end-to-end approach, satisfying the needs of both oilseed growers and consumers.

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GUIDELINES TO THE CONTRIBUTORS

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

Manuscripts, in triplicate, neatly typed in double space on one side of the white paper (A4 size) can be submitted through the Registered Post to the **Chief Editor, Journal of Oilseeds Research, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Andhra Pradesh (India). The revised manuscript must accompany a CD (only CD is allowed) having article typed and saved in MS Word. Chief Editor can be contacted at e-mail: harvir@gmail.com**

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

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

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