Journal of Oilseeds Research

Volume 23
Number 2
December, 2006
ISSN 0970-2776

Indian Society of Oilseeds Research
Directorate of Oilseeds Research

THE INDIAN SOCIETY OF OILSEEDS RESEARCH

(Founded in 1983, Registration Number ISSN 0970-2776)

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Indian Society of Oilseeds Research thankfully acknowledges the financial assistance received from INDIAN COUNCIL OF AGRICULTURAL RESEARCH, New Delhi for printing this Journal

Journal of Oilseeds Research is published biannually by the Indian Society of Oilseeds Research

ISSN 0970-2776
Volume 23
Number 2
December, 2006

Journal of OILSEEDS RESEARCH

Contents

DOR-370.

Research Papers

Official publication of
The Indian Society of Oilseeds Research, Hyderabad
***J. Oilseeds Res.*, 23(2) : 144-380 (December, 2006)**

Short Communications

J. Oilseeds Res., **23(2) : 144-150 (2006)**

Review Article

Etiology, epidemiology and management of *Botrytis* grey mold of castor, *Ricinus communis* L. - A review

M.A. Raoof and Mehtab Yasmeen

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP

(Received: February, 2006; Revised: March, 2006; Accepted: June, 2006)

Abstract

Grey mold caused by *Botrytis ricini* Godfrey is becoming a serious threat to castor (*Ricinus communis* L.) cultivation especially in peninsular India where the crop is devastated during cyclonic and incessant rains. Continuous wet and humid conditions during flowering and capsule development stages for 5-7 days leads to severe rotting of infected spikes and epidemic spread of the disease. Yield loss is severe as cultivars with high level of disease resistance are not yet available and chemical control is not very effective due to inclement weather. To surmount the disease, a clear understanding of survival, spread, existing and alternative management strategies of the pathogen are very important. In this review the information on etiology, epidemiology and different methods of grey mold management in castor has been compiled and discussed in relation to grey mold diseases on other crops.

Key words: Grey mold, *Botrytis ricini*, castor, etiology, epidemiology, management

Introduction

Grey mold epidemic was first reported from Florida, U.S.A in 1918 when a large part of the State was devoted for the cultivation of castor (*Ricinus communis* L.) crop during war emergency to meet the increasing demand of castor oil. A large quantity of castor seeds was imported during that year to Florida from India and it appears that the fields where the disease developed were those in which imported seeds were sown (Godfrey, 1923). The presence of grey mold in Karnataka, India was confirmed by Dastur (Anon., 1921). The occurrence of the disease was recorded from Russia (Tropova, 1928), Germany (Palm, 1932), Brazil (Viegas, 1944), Morocco (Rieuf, 1953), Jamaica (Wright, 1954), Rhodesia (Anon., 1959), Bulgaria (Vanev, 1960), Nigeria (Esuruoso, 1966), British Columbia (Patino, 1967), Australia (Anon., 1970) and Thailand (Thammasak-Sommarty, 1983). An epidemic of grey mold was reported from Mississippi, U.S.A during 1958 (Stone and Culp, 1959). The disease first appeared in epidemic form in Andhra Pradesh, India during 1987 (Moses and Ranga Reddy, 1989) and since then its increased occurrence has been recorded in southern and eastern India.

Etiology

Godfrey (1919) had first reported the fungus as a new species of *Botrytis* parasitic on inflorescence, stem and leaves of castor in the U.S.A and described the perfect stage as *Sclerotinia ricini* Godfrey. Whetzel (1945) placed the fungi belonging to family Sclerotineaceae whose asexual conidial stage is known in the genus group *Botryotinia* and whose asexual conidial stage is unknown were kept in type genus *Sclerotinia*. Accordingly, the pathogen on castor was renamed as *Botryotinia ricini* (Godfrey) Whetzel [= *Sclerotinia ricini* Godfrey] (Orellana, 1959). *Botryotinia ricini* was first reported from India in 1921 (Anon., 1921). Buchwald (1949) first named the imperfect stage of the fungus as *Botrytis ricini* (Godfrey) Buchwald. Golenia (1955) reported *Botrytis cinerea* Pers. Ex. Fr. to cause grey mold of castor. The *Botrytis* species tend to be concentrated in the temperate regions of the world, where they occur on a variety of crop plants. The types grouped under *B. cinerea* have a very wide host range and are known to cause grey mold in grapes (Nelson, 1951), strawberries (Jorden and Hunter, 1972), sunflower (Mathur *et al.*, 1981), chickpea (Haware and Nene, 1982), blackberry and raspberry (Bristow, 1991), cucumber (Elad and Yunis, 1993), roses (Elad *et al.*, 1993), geranium (Sirjusingh *et al.*, 1996), tomato (O'Neill *et al.*, 1997) and sweet cherry (Adaskareg *et al.*, 2000) etc. The perfect stage of *B. cinerea* is *Botryotinia fukeliana* (de Bary) Whetzel (Grooves and Loveland, 1953) that has so far not been reported from India (Rathi and Tripathi, 1993). The genus *Botrytis* contains a large number of host-specific pathogens such as *B. fabae* Sardina on beans and *B. aclada* Fresenius on *Allium* spp. and other species (Coley-smith, 1980). Though the branching pattern of conidiophores and culture characteristics of *B. ricini* and *B. cinerea* are similar they could be

differentiated based on the conidia shape, *B. ricini* conidia are globose whereas that of *B. cinerea* are oval to elongate (Ellis, 1977). Raoof (Anon., 2000) confirmed the host specificity of *B. ricini* by cross inoculation test under artificial epiphytotic conditions. A detailed description of *B. ricini* is given by Godfrey (1919; 1923), which is as follows: The fungus forms wide spreading cob-webby somewhat wooly mass, pale drab-grey to drab, dried specimens dark olive grey; sterile hyphae procumbent, hyaline, many septate often vacuolated frequently anastomosing; fertile hyphae produce long, slender, smooth, hyaline, septate hyphae slightly constricted at the base, olivaceous when mature, dichotomously branched terminal branching compact, apices non-inflated, thin walled collapsing when the conidia fall; conidia borne on sterigmata, globose, smooth, hyaline, 6-12 µ and compactly grouped (Fig.1); sclerotia black, rough, elongate, irregular, 1-25 mm in length, sub-erumpent to superficial developing on axes and peduncles of old castor inflorescences and on stalks; the fungus grows very rapidly on artificial media, spreading and superficial at first, with glistening appearance on the surface of the medium, within 48 hr aerial hyphae begin to develop which produce conidia and the culture attains light grey colour and gradually change to drab or even dark-olive grey. about the fourth day sclerotia ½ mm to 3 or 4 mm in length, at first pale smoke grey then gradually darker in colour finally changing to black begin to form. Based on the diffused and grey colour of the colonies on Potato Dextrose Agar (PDA), erect conidiophores, seldom branched, septate, 11-23 µ thick, with several projections on the tips on which thick beads of hyaline, globose, conidia 8-9 µ diameter Moses and Ranga Reddy (1989) established the causal agent of castor grey mold in India as *B. ricini*. Mehtab Yasmeen (2004) observed the formation of sclerotial bodies on PDA, castor leaf extract medium and V_8 juice medium.

Godfrey (1919) also observed the production of perfect stage *Sclerotinia ricini* from sclerotia under natural as well as laboratory conditions. The following are the characteristics of the perfect stage: A single sclerotium produces one to several apothecia (Fig.2) each measuring 5-30 mm high (usually 6-15 mm), infundibuliform to cyathium and discoid, long stipitate, cinnamon brown to chestnut brown, stalk concolorous, cylindrical, slender, smooth, flexuous, attenuated below, without rhizoids; disc at first closed, expanding to saucer-shaped with margin sometimes recurved, exterior roughened, 1-7mm in diameter (usually 1.5-4mm); asci cylindrical to cylindro-clavate, apex slightly thickened, opening by a pore, 50-110 µ by 6-10 µ (usually 80 - 100 µ by 8 µ); with eight spores, ellipsoidal, often sub-fusoid, hyaline, continuous, bi-guttulate, 9-12 µ by 4-5 µ; paraphyses abundant, filiform, septate, hyaline, 1.5-2 µ in diameter (Fig.3).

Epidemiology

Botrytis ricini survives in soil through mycelia or dormant structures called 'sclerotia' formed on the infected castor crop debris/seeds (Godfrey, 1923). In the U.S.A, sporogenic and carpogenic germination of sclerotia were observed under artificial as well as natural conditions. The fungus was found to survive in infected castor crop debris for six and nine months under field and laboratory conditions, respectively (Mehtab Yasmeen, 2004). On the contrary *B. cinerea* was found to survive under field conditions in infected chickpea plant debris at a depth of 25 cm for eight months (Singh and Tripathi, 1992). In India, sclerotia of *B. ricini* are rarely found on infected castor plant parts. Even those formed on artificial media germinate only by myceliogenic/sporogenic means (Mehtab Yasmeen, 2004). Godfrey (1923) observed the grey mold growth both on the caruncle of the seed and also beneath the seed coat with mycelial fragments on and inside the seed surface and sclerotia formed on infected seeds produced apothecia even after 17 months. The seed-borne nature of the pathogen was confirmed by many workers (Kulkarni and Ramanamurthy, 1977; Srinivasulu *et al.*, 1994). Similarly seed-borne nature of *B. cinerea* in chickpea has also been reported (Laha and Grewal, 1983). Latent infection in castor seeds collected from apparently healthy capsules of infected plants was also reported (Mehtab Yasmeen, 2004). Jarvis (1962) found latent infection of *B. cinerea* in strawberries and raspberry fruits while McClellan and Hewitt (1973) observed quiescent infection in the stylar end of the grapes. Tikhonov and Andreeva (1986) observed seedling infection when the seeds from previously infected crop were sown under humid conditions. Infected seedlings and sprouts perish and tissues of seedlings, cotyledonary leaves and stems turn brown, mold and soften and finally young plants die.

The disease appears at flowering or capsule development stage with the prevalence of continuous cyclonic weather in southeast coastal regions of India for a few days, which results in high humidity build up coupled with low temperature conditions. Godfrey (1923) reported a succession of several continuous wet days with high relative humidity (> 90%) and moderate temperatures (25-28°C) as essential for grey mold development in castor. Moses and Ranga Reddy (1989) reported prolonged wet conditions as congenial for disease development, sporulation and spread. Abundant sporulation on the infected racemes provides incoculum that is readily disseminated by wind and splashing rain, which facilitates the spread of secondary infection. Jarvis (1962) found air currents and splashing rain to disseminate spores of *Botrytis* sp. in the field for secondary infection.

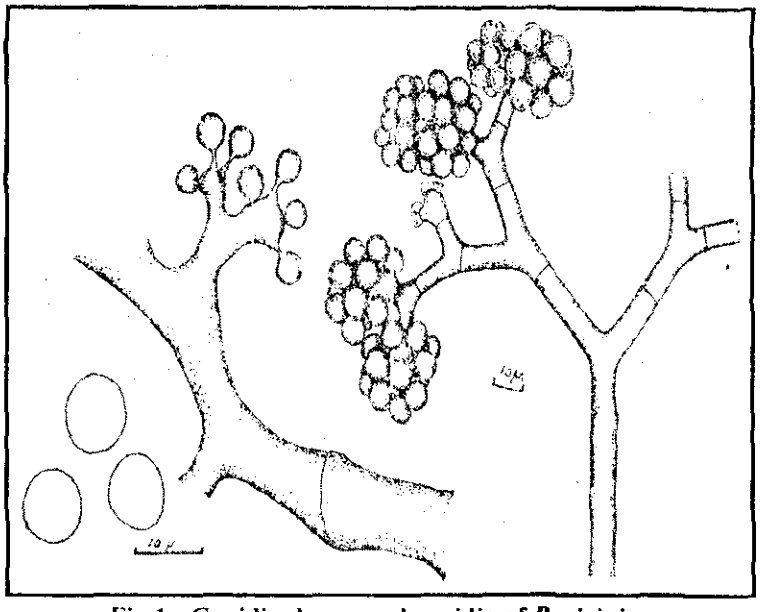

Fig.1: Conidiophores and conidia of *B. ricini*

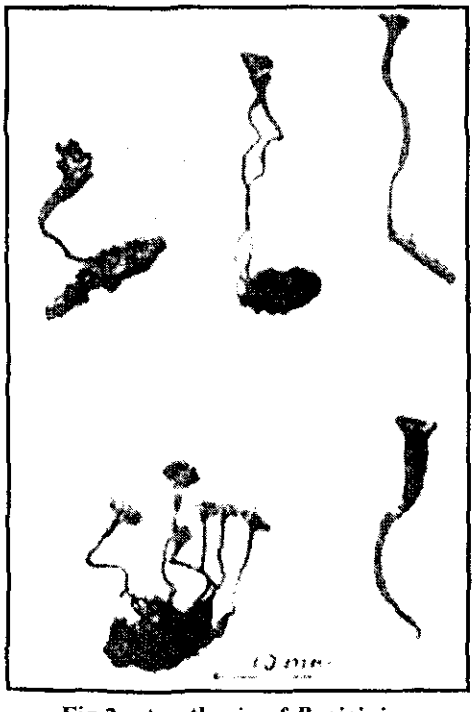

Fig.2: Apothecia of *B. ricini*

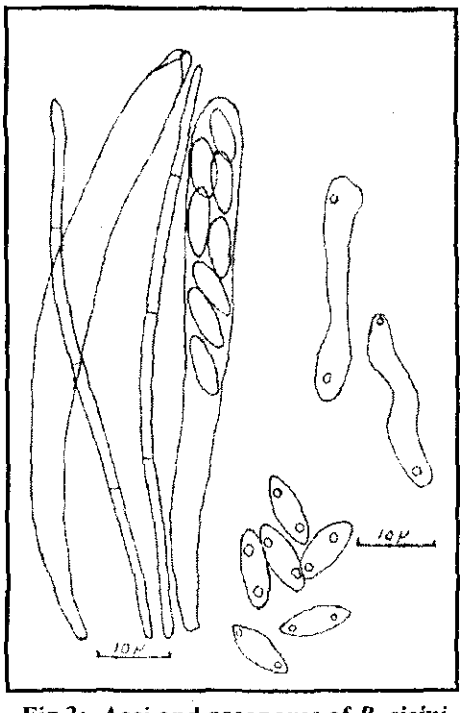

Fig.3: Asci and ascopores of *B. ricini*

(Adopted from Godfrey, 1919)

Host range

While Godfrey (1923) reported *B. ricini* infection on *Jatropha* sp., *Manihot utilissima* and *Euphorbia pulcherrima*, under artificial inoculated conditions Mehtab Yasmeen (2004) found *B. ricini* to infect eight members of the family Euphorbiaceae (*Euphorbia hirta*, *E. geniculata*, *E. pulcherrima*, *E. prostrata*, *Jatropha curcus*, *J. intergerrima*, *J. multifida*. *J. podagrica* and *J. gossypifolia*) and five species belonging to different families *viz.*, *Hibiscus rosa-sinensis* (Malvaceae), *Helianthus annuus* and *Tagetus errecta* (Asteraceae), *Cicer arietinum* and *Delonix regia* (Fabaceae) and *Bougainvillea spectabilis* (Nyctaginaceae) Similarly, Rathi and Tripathi (1991) also observed *B. cinerea* to infect eight cultivated species and 21 weeds under artificial inoculated conditions.

Disease Management

Host resistance has been on top priority to manage castor grey mold. However, to identify resistant sources reliable screening techniques are prerequisite. At Directorate of Oilseeds Research, Rajendranagar (Anon., 2000) two screening techniques *viz.*, 'detached spike technique' and 'field screening technique' were developed for screening castor germplasm and breeding material against grey mold disease. At G.B. Pant University of Agriculture and Technology, Pantnagar 'flower culture technique' was used for artificial screening (Rathi and Tripathi, 1994). At ICRISAT three screening techniques *viz.*, 'cut-twig screening technique' (Singh *et al.*, 1998) 'growth room screening technique' and 'field screening technique' (Pande *et al.*, 2002) were developed to screen chickpea germplasm and breeding material for grey mold resistance. Thomas and Orellana (1963) reported cultivars of castor with spiny capsules borne in compact racemes to be more susceptible to grey mold than spineless capsules in open raceme types. Sall *et al.*, (1981) reported grape cultivars with tight cluster to be susceptible to severe bunch rot caused by *B. cinerea* than cultivars with loose fruit clusters. In chickpea, tall, erect and compact genotypes exhibited resistance to grey mold than bushy and spreading genotypes (Haware and Mc Donald, 1993). Raoof and Nageshwar Rao (1999) found spineless castor variety 48-1 (Jwala) to be less susceptible to grey mold. Out of 145 castor germplasm accessions screened against grey mold under artificial epiphytotic conditions at Directorate of Oilseeds Research, Hyderabad only six accessions were identified as moderately resistant (Anjani *et al.*, 2004). In chickpea genotypes too, high levels of resistance against grey mold is not available (Rathi *et al.*, 1984). Work on induction of host resistance in castor against grey mold using mutations (gamma radiations) is in progress and resistant/tolerant mutant thus identified can be either directly be released or used for breeding resistant cultivar (Anon., 2005).

Removal and burning of grey mold infected castor spikes/capsules has been recommended (Anon., 2002) for reducing the inoculum load of the pathogen. Removal and burial or burning of decaying infected plant tissues were proven as a practical measure to reduce *Botrytis* inoculum levels in field in crops like tomatoes, peony, lettuce, grapes and tulips (Maude, 1980) Wider spacing between the plants and between rows (90 x 60 cm) has also been recommended as one of the important components for castor grey mold management (Anon., 2002) as it provides good aeration in the crop canopy and reduces the wetness of the tissue thus reducing disease development. Broad bean crop sown at wider spacing (46 x 71 cm) were less severely attacked by *B. fabae* than those sown more densely (30 cm apart and less). Wider spacing between rows resulting in low incidence of chickpea grey mold was reported from Nepal (Reddy *et al.*, 1988), India (Reddy *et al.*, 1993) and Bangladesh (Bakr *et al.*, 1993). Adjusting sowing time such that the crop maturation occurs during dry season helps in disease escape (Raoof and Nageshwar Rao, 1999). Karki *et al.*, (1989) also observed reduced grey mold incidence in chickpea by adjusting sowing time.

Tropova (1928) reported that disinfection of castor seeds with a higher concentration of formalin than usually used for seed disinfection considerably reduced the incidence of *Botrytis* along with other seed-borne fungi. Kanwar and Khanna (1979) reported that seed treatment with benomyl @ 0.25% completely controlled all the fungi associated with seeds of castor while Siddaramaiah *et al.* (1980) found agallol (3g/kg) and thiram (3g/kg) to be effective. Srinivasulu *et al.* (1994) tested six fungicides out of which maximum control was obtained with carbendazim followed by captan. Madhu Meeta *et al.* (1986) and Rewal (1987) reported that spraying with carbendazim (0.1%) or carbendazim + thiophanate methyl (0.1%) significantly reduced grey mold intensity in chickpea. Fungicides *viz.*, Iprodione, Vinclozolin, Procymidone, Dichlofluanid and Folpet reduced grey mold incidence in grapes (Mlikota *et al.*, 1996). Incorporation of weather forecasting in integrated disease management module is essential for timely management of grey mold in the fields as the disease development is entirely weather dependant. Forecasting system BOTMAN (Shtienberg and Elad, 1997) and predictive model (Bakr *et al.*, 1999) were developed for management of vegetable crops and chickpea against grey mold, respectively. Depending on Area Cyclone Warning Centre's forecast, one spray of carbendazim/thiophanate methyl 1g/l before onset of cyclonic weather and one more spray after disease appearance were recommended as chemical control for castor grey mold (Anon., 2002).

Raoof *et al.* (2003) reported *Trichoderma* spp. and *Pseudomonas fluorescens* to control castor grey mold to an extent of 40-50% under artificial inoculation conditions. Mukherjee and Haware (1993) isolated and tested many *Trichoderma* spp. against *B. cinerea* causing grey mold of chickpea and obtained considerable success in laboratory as well as in field conditions. Induced systemic resistance against castor grey mold was obtained by applying salicylic acid at 10 mM concentration on the racemes one week before inoculation of *B. ricini* under artificially inoculated conditions (Aswani Kumar, 2001). Similarly salicylic acid reduced grey mold incidence in tomatoes (Elad, 1993), pepper (Elad, 1993) and lilium (Chen-Chaoying *et al.*, 1997). Synthesis of phytoalexins through heterologous expression of resveratrol synthase from grapevine rendered tobacco more resistant to *B. cinerea* (Hain *et al.*, 1993). Transgenics in cucumber (Tabei *et al.*, 1998) and chrysanthemum (Takatsu *et al.*, 1999) were developed against grey mold by expressing rice chitinase cDNA. Expression of pear polygalacturonase inhibitor protein (PGIP) in transgenic tomato plants enhanced resistance of tomato leaves and fruits to *B. cinerea* (Powell *et al.*, 2000) Efforts are also under progress to develop transgenic chickpea by utilizing the gene encoding raspberry PGIP (Anon., 2002). Recently Hinrichsen *et al.* (2005) reported that introduction of *Trichoderma harzianum* anti-fungal genes and anti-microbial peptide genes into grapes provided significant reduction in size of lesions caused by *B. cinerea* on leaves.

Conclusion

Castor is a mainstay of rainfed production systems especially when the monsoon outbreaks lately. Information on castor grey mold is very meager. Stable and reliable sources of resistance need to be identified by screening under varied agroclimatic conditions at hot spot locations. It is also essential to study the basis of resistance in castor for genetic engineering to develop transgenic cultivars. Systematic studies on ecology and epidemiological factors need to be carried out for development of forewarning systems to manage the disease in a cost-effective way, since many castor farmers are resource-poor. Biocontrol agents need to be exploited for control of moderate infections. In the light of its infectivity on *J. curcus,* care may be initiated to protect the large-scale plantings being promoted for harvesting bio-diesel from this crop.

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J. Oilseeds Res., **23**(2) : 151-155 (2006)

Genetic divergence and stability analysis in Indian mustard, *Brassica juncea* (L.) Czern & Coss

K.H. Singh, K.K. Srivastava, J.S. Chauhan and Arvind Kumar

National Research Centre on Rapeseed Mustard, Sewar, Bharatpur-321 303, Rajasthan

(Received: June, 2005; Revised: September, 2006; Accepted: October, 2005)

Abstract

Genetic divergence was examined in 22 released varieties and one advanced line of Indian mustard [*Brassica juncea* (L) Czern & Coss]. Considerable variability was observed for 1000-seed weight, seed yield, total biomass, plant height, harvest index and days to flowering. The variability was low for oil content, protein content, seeds/siliqua and maturity duration. Genotypes were grouped into 5 clusters. Varuna, Vaibhav, RL-1359 and Bio 902 were stable varieties for seed yield. Vardan and Seeta were found suitable for low input cultivation, while, Krishna was found suitable for input rich cultivation. Crossing of the parents Bio 902, Varuna, RH 30 and Bio 772 with Seeta would be desirable for combining earliness, short plant height, bold seed and high oil content with high seed yield.

Key words: Genetic divergence, stability, variability, Indian mustard, *Brassica juncea*

Introduction

In India, rapeseed mustard occupies second place in terms of area and production after groundnut. Rapeseed - mustard has witnessed significant increase in area, production and productivity since the inception of Technology Mission on Oilseeds and Pulses in 1986. The production and yield of rapeseed mustard have increased from 2.68 m.t. and 674 kg/ha in 1985-86 to 3.97 m.t. and 902 kg/ha, respectively, in 2002-03 (Anonymous, 2003). Development and adoption of high yielding varieties have been instrumental in increasing the yield and production. Varietal development programme, which initiated with the release of T-11 in 1936, has resulted in the notification of 105 varieties of rapeseed mustard by 2005. Of these, 90 were developed after the inception of the All India Coordinated Research Project on Oilseeds in 1967 (Chauhan *et al.*, 2003).

In the present study 22 popular varieties of Indian mustard [*Brassica juncea* (L.) Czern & Coss], which are widely grown in different agro-climatic zones of the country along with one advanced entry were chosen. The study was carried out for 3 years starting from the year 1998-99. The variability among the varieties/genotype for seed yield and nine yield related traits as well as stability of these varieties was analysed.

Material and methods

Twenty two high yielding varieties of mustard developed during 1975 to 1998 in India and one promising advanced breeding strain selected from advanced yield evaluation trials during 1996-97 were chosen for present investigation (Table 1). Breeder seeds of these varieties were procured from the concerned breeders. All the 23 genotypes were grown in 10 rows of 5 m length in Randomized Complete Block Design with 3 replications. Row to row and plant-to-plant spacings were maintained at 30 and 10 cm, respectively.

Observations were recorded for 10 traits including plant height (cm), days to 50% flowering, days to maturity, seeds per siliqua, 1000 - seed weight (g), seed yield (kg), total biomass (kg), harvest index (%), oil and protein content (%). Plant height and seeds/siliqua were recorded on 10 randomly selected plants from each genotype, while, days to flower and maturity, seed and biomass yield were recorded on the plot basis. 1000-seeds weight, oil content and protein content were recorded by taking random samples from plot yield. Harvest index was computed as ratio between seed yield and biological yield and expressed in percentage. Variability was studied on the basis of mean values pooled over 3 years data. Bartlett's test was applied to test the homogeneity of variance and weighted analysis was used where year x variety interaction was absent and error variance was heterogenous, to make comparison among varietal mean (Panse and Sukhatme, 1985).

Stability analysis was conducted using 3 years data following Eberhart and Russell (1966) to determine stability regression co-efficients and deviations from regression. The mean square for deviations from regression was tested against the residual mean square using the appropriate test suggested by Eberhart and Russell (1966). Genetic diversity among the varieties was determined by using Mahalanobis's (1928) D^2 statistics and varieties were grouped into different clusters.

Table 1 Name, year of release, pedigree and area of adoption of mustard varieties

Name	Year of release	Pedigree	Area of adoption
Varuna	1975	Pureline selection from Varanasi Local	Entire mustard growing region of te country
Seeta	1980	Pureline selection from germplasm collected from West Bengal	Rainfed and irrigated areas of West Bengal
Kranti	1982	Selection from Varuna	Irrigated areas of Bihar, Delhi, Gujarat, Haryana, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal
Krishna	1983	Selection from Varuna	Irrigated areas of Bihar, Delhi, Haryana, Madhya Pradesh, Orissa, Pubjab, Rajasthan and Uttar Pradesh
RH-30	1983	Selection from P 26/3-1	Rainfed and irrigated areas of Haryana, Jammu, Punjab, North Rajasthan and Western Uttar Pradesh
RLM 619	1983	Gamma ray induced mutant olf RL 18	Irrigated areas of Gujarat, Haryana, Jammu, Punjab and Rajasthan
RH 8113	1985	Derived from the cross Varuna x RC 781	Irrigated areas of Haryana, Himachal Pradesh, Jammu, Punjab and Rajasthan
Rohini	1985	Selection from Varuna	Madhya Pradesh and Uttar Pradesh
Vaibhav	1985	Derived through biparental mating involving Varuna, Keshri, CSU 10, IB 1775, IB 1786 and 1886	Rainfed and irrigated areas of Madhya Pradesh and Uttar Pradesh
Vardan	1985	Derived through biparental mating involving Varuna, Keshri, CSU 10, IB 1775, IB 1786 and 1886	Irrigated areas of Madhya Pradesh and Uttar Pradesh
RL 1359	1987	Derived from the cross RLM 514 x Varuna	North-West Zone of India
RH 781	1990	Derived from the cross RL 18 x 26/3-1 x RL 18	Irrigated areas of Haryana and Eastern zone of India
RH 819	1990	Derived from the cross Prakash x Bulk pollen	Rainfed areas of North West Zone
Bio 902	1993	Somaclone of Varuna	Irrigated areas of Gujarat, Maharashtra and Western Rajasthan
PCR 7	1993	Pureline selection from Kutch germplasm line JMG 36-6	Rainfed and irrigated areas of Gujarat, Maharashtra and Western Rajasthan
PBR 91	1994	Derived from the three way cross (RLM 511 x PR 18) x CM-1	Punjab
PR 6988	1995	Derived from the cross PR 8611 x Varuna	North West Zone of India
RH 8812	1996	Derived from the cross PR 15 x RH 30	Haryana
CS 52	1997	Pureline selection from DIRA 343	Sodic and saline soils of Haryana, Rajasthan and Uttar Pradesh
SEJ 2	1997	Derived from the cross early maturing *Brassica juncea* x synthetic amphidiploids (*B. campestris* var *toria* x *B. nigra*)	Irrigated areas of Delhi, Haryana, Punjab and Rajasthan and rainfed areas of Assam, Bihar, Jharkhand, Orissa, Chhattisgarh
RN 393	1998	Derived from the cross Krishna x RS 50	Rainfed situation of Haryana, Punjab and Rajasthan
VSL 5	1998	Derived from the cross Varuna x Synthetic juncea	Irrigated areas of Madhya Pradesh, Rajasthan and Uttar Pradesh
Bio 772	-	-	-

Results and discussion

Results of the present study are being discussed in terms of variability existed in the varieties; performance of these varieties/genotype for different traits in comparison to Varuna (national check) and strategy to combine the desirable traits through hybridization followed by selection.

Variability and genetic divergence: Phenotypic coefficient of variation (Table 2) suggested existence of diversity among the 23 genotypes tested in this study. Considerable variability was observed for plant height, days to 50% flowering, test weight, seed yield and biomass yield but low for seeds/siliqua, harvest index, protein and oil content. Variation in plant height, flowering and maturity duration makes these varieties suitable for cultivation under different agro-climatic zones. However, there is need of further improvement for seeds per siliqua, harvest index, oil and protein content, which will result in higher oil yield.

Table 2 Mean values of different traits and stability parameters for seed yield in 23 genotypes of Indian mustard

Variety	Seed yield (kg/ha)	Regression coefficient	Deviation from regression (SD)	Plant height (cm)	Days to flowering	Days to maturity	Seeds/ siliqua	1000-seed weight (g)	Biological yield (q /ha)	Harvest index (%)	Oil content (%)	Protein content (%)
VARUNA	1750	0.724	-0.73	171	56	133	12	6.1	69.4	25.2	39.2	21.2
RH 781	1410	1.28	2.75*	183	59	136	13	4.1	61.4	23.1	39.9	22.0
VSL-5	1620	1.9	-0.68	165	53	132	13	4.3	68.4	23.9	39.6	22.0
RN 393	1530	0.66	1.15	181	62	140	13	4.2	71.3	21.5	39.5	22.3
RH 819	1410	0.29	2.67*	191	66	138	13	4.3	65.8	21.6	40.2	22.2
VARDAN	1550	-0.8	-0.74	164	56	131	13	3.7	66.3	23.6	40.9	21.7
VAIBHAV	1680	0.86	1.29	151	53	132	12	4.3	71.0	24.8	39.2	21.6
RBR-91	1620	2.05	1.49	186	60	137	13	4.0	72.4	22.5	38.6	21.9
PCR-7	1650	2.25	6.28	185	65	139	13	4.8	74.2	22.2	39.6	21.7
KRISHNA	1640	1.45*	-0.75	177	58	137	14	4.3	71.6	23.2	40.2	21.9
RH- 30	1430	1.59	1.41	175	56	135	12	5.7	62.5	22.8	39.5	21.5
SEETA	1260	-0.32	-0.71	149	47	125	13	3.1	50.9	24.9	41.6	21.7
RH 8113	1460	1.6	0.07	194	62	139	13	3.9	69.6	21.0	39.6	22.3
KRANTI	1540	2.55	2.56*	178	61	137	13	4.0	69.7	21.8	40.0	22.0
PR 8988	1430	2.03	-0.68	187	59	136	12	4.5	64.7	22.3	39.6	21.8
CS-52	1510	0.25	-0.55	183	59	135	13	4.3	66.5	23.2	39.8	21.7
SEJ-2	1310	-0.44	-0.16	155	44	122	13	4.6	61.4	21.4	40.7	21.4
RL 1359	1680	1.31	-0.59	183	58	137	14	4.3	71.6	23.4	40.6	21.9
BIO 772	1670	1.72	-0.69	164	55	134	13	6.2	67.9	24.7	39.6	20.9
ROHINI	1390	0.44	-0.42	166	60	136	13	4.5	59.5	23.6	40.1	21.4
RLM 619	1480	0.59	-0.29	177	58	133	13	4.8	60.0	24.8	39.9	21.5
RH 8812	1470	-0.35	-0.04	182	59	139	14	5.0	65.8	22.4	40.3	21.9
BIO 902	1680	1.37	0.44	162	55	136	13	6.1	64.9	25.9	38.8	21.2
CD (P=0.05)	130			14.5	6.48	2.41	2.07	0.39	8.0	2.4	1.47	0.99
PCV*	17.7			16.2	11.6	6.0	9.9	21.3	18.7	13.5	4.2	5.7

PCV = Phenotypic coefficient of variation

On the basis of D^2 values, 23 genotypes were grouped into five clusters. Cluster 1 was the biggest cluster comprising 16 varieties. Cluster II comprised of four varieties while, clusters III, IV and V consisted only one variety each (Table 3). The perusal of the Table 4 revealed that cluster II and IV were most distant from each other followed by cluster IV and I. In contrast cluster I and III were closely placed to each other. This is to be noted that cluster IV comprises only one variety "Seeta" which is adopted in West Bengal while the varieties of cluster I and II are well adopted in the northern parts of the country, suggesting the effect of geographical distance on genetic diversity. Intra cluster distance was highest among the genotypes falling in cluster I, which was the biggest cluster. Cluster means for 10 different traits are presented in Table 5. Plant height ranged from 148.6 (Cluster IV) to 178.7 (cluster I). Obviously tall varieties were grouped in cluster I while, cluster IV comprised of single variety *viz.*, Seeta with shortest plant height. Days to 50% flowering was lowest in cluster V (SEJ-2) and highest in cluster I. On the basis of seed yield and seed weight, cluster II had most valuable genotypes *viz.*, Bio 772, Bio 902, Varuna and RH-30.

A perusal of the pedigree (Table 1) of these 23 genotypes exhibited that nine genotypes were either selection from Varuna or involved Varuna as one of the parents. Out of these nine genotypes, 8 fell in the same cluster I. It was, however, interesting to note that Varuna was in different cluster (cluster II) with Bio 902, RH 30, and Bio 772. This was also obvious that the genotype SEJ-2, which included synthetic amphidiploids as one of the parents was single genotype in the cluster V, representing its diversity from the other genotypes. Genotypes Vardan and Vaibhav, which have the similar ancestry, belonged to different

clusters suggesting different genetic make up as a result of biparental mating. On the basis of pedigree as well as genetic diversity reflected by D^2 analysis, it would be desirable to cross the parents from cluster I and II with that of cluster III, IV and V (each monogenotypic) to create considerable magnitude of variability and to identify heterotic parental combinations.

Table 3 Number and name of genotypes in different clusters

Cluster	No. of genotypes	Genotype
Cluster I	16	Krishna, RL 1359, RN 393, CS 52, RH 781, PR 8988, RH 8113, Kranti, Rohini, RLM 619, PBR 91, VSL-5, PCR-7, RH 8812, RH 819, Vardan
Cluster II	4	Bio 772, Bio 902, Varuna, RH 30
Cluster III	1	Vaibhav
Cluster IV	1	Seeta
Cluster V	1	Sej-2

Table 4 Intra (diagonal) and inter cluster distance (D^2 values) of the cluster

Cluster	I	II	III	IV	V
I	5.7	11.8	8.7	12.8	10.7
II		5.1	11.5	20.2	12.7
III			0.0	12.7	10.6
IV				0.0	10.4
V					0.0

Stability analysis: Development of a stable variety is one of the major objectives of all breeding programmes. Several models have been proposed for stability analysis. According to Eberhart and Russell (1966) model a stable variety is one, which has above average mean yield, a regression coefficient of unity (=1.0) and non-significant mean square for deviations from regression (SD = 0). High value of regression (>1.0) indicates that the variety is more responsive for input rich environment, while, low value of regression (<1.0) is an indication that the variety may be adopted in poor environments.

Analysis of variance for stability of yield (Table 6) revealed the existence of substantial variability among varieties for seed yield. Significance of variety x year interaction revealed that varieties interacted significantly with environments (years). The partitioning of interaction showed that both linear and non-linear (pooled deviation) components of interaction were highly significant.

The phenotypic stability of varieties was estimated by mean performance over years (x), the regression coefficient (b) and the deviation from regression. In Eberhart and Russel model 'b' is considered as a measure of responsiveness and S^2di (pooled deviation), as a measure of stability. Varieties viz., Varuna, Vaibhav, RL 1359, Bio 902 had regression near to unity, non-significant pooled deviation and above average yield therefore, may be grouped as stable. Singh et al. (2002) also recommended RLM 1359, RH 30, Varuna, Kranti, Rohini and PCR-7 for cultivation under irrigated clay loam soil of semi arid tract of eastern Rajasthan. Vardan and Seeta had significant negative regression coefficient, which indicated that these varieties may be adopted to poor environments. On the other hand, the regression coefficient of Krishna was more than one and significant indicating thereby its responsiveness to favourable environments. Deviation from regression was significant for the varieties RH 781, RH 819, PCR 7 and Kranti indicating their highly unpredictable response over the years.

Table 5 Cluster means of five clusters for 10 quantitative traits in Indian mustard

Cluster	Plant height (cm)	Days to 50% flowering	Days to maturity	Seeds/ siliqua	1000-seed weight (g)	Seed yield (q/ha)	Biomass yield (q/ha)	Harvest index (%)	Oil content (%)	Protein content (%)
I	178.7	59.9	136.2	13.0	4.3	15.2	67.4	22.7	39.9	21.8
II	167.8	55.7	134.4	12.4	6.0	16.3	68.7	23.9	39.3	21.1
III	151.1	52.8	132.0	12.0	4.3	16.7	70.9	24.8	39.3	21.6
IV	148.6	46.2	123.8	13.3	3.1	12.6	50.9	24.9	41.7	21.6
V	155.1	44.9	121.5	13.3	4.6	13.1	61.4	21.4	40.7	21.4

Stability analysis however, revealed that Varuna, Bio 902, RL 1359 and Vaibhav were more stable varieties for seed yield. It was also obvious from comparison of mean values for 10 traits that few varieties performed better than Varuna for plant height, days to flower, maturity duration, oil and protein content but still none of the released varieties could surpass it for seed weight, biomass production and harvest index. Therefore, it would be desirable to create variability through hybridization followed by selection to identify better genotypes for these traits. The genetic diversity has a direct relation on the creation of magnitude of variability through hybridization.

Table 6 Analysis of variance for stability of yield

S.V.	d.f.	M.S.
Varieties	22	5.1**
Environment + (Variety x Environment)	46	5.9**
Environments	2	66.6**
Variety x Environment	44	3.2*
Environment (Linear)	1	133.3**
Variety x Environment (Linear)	22	5.1**
Pooled deviation	23	1.3**
Pooled Error	138	0.7
Total	68	5.7

The genotypes from diverse clusters should be used rather than the genotypes of clusters having low divergence to create variability for further selection in subsequent generations and to identify heterotic cross combinations for harvesting hybrid vigour. Singh and Gupta (1985), Pradhan *et al.* (1993), Ali *et al.* (1995) and Ghosh (2002) also suggested the use of diverse parents for hybridization programme.

Results of present experiment showed that crossing parents from cluster I and II with varieties *viz.*, Vaibhav, Seeta and SEJ-2 which belong to cluster II, IV and V, respectively will result in considerable variability and genotypes with combined traits for early maturity, short plant height, high seed yield, bold seeds and high oil content may be developed.

Acknowledgement: Financial assistance received under NATP MM Sub-Project "Development of Hybrids-crop: Rapeseed-Mustard" is thankfully acknowledged.

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J. Oilseeds Res., **23**(2) : 156-158 (2006)

Genetic divergence analysis in Indian mustard, *Brassica juncea* (L.) Czern & Coss

R.K. Solanki, R.S. Tomar and M.D. Arha

Seed Technology, Sardarkrushinagar-Dantiwada Agril. University, Sardarkrushinagar-385 506, Gujarat

(Received: September, 2005; Revised: December, 2005; Accepted: January, 2006)

Abstract

Genetic diversity studied by using Mahalanobis D^2 statistics indicated wider genetic diversity in the population of Indian mustard. The 32 Indian mustard genotypes studied, grouped into six clusters. Cluster VI genotypes showed maximum value for plant height (197 cm), number of siliquae/plant (368) and number of seeds/siliqua (17). Whereas, genotypes of cluster VI showed maximum value for seed yield/plant (27.2 g), number of branches/plant (32) and oil content (38.5 %). Cluster I recorded genotypes with lowest mean values for days to 50 % flowering (42.4). Plant height contributed the maximum to the total divergence (40.5%) followed by days to maturity. The clustering pattern did not establish a clear-cut relationship between genetic diversity and geographical diversity. The cultivars included in the diverse clusters can be used as promising parents for hybridization programme for obtaining high heterotic response and thus better segregants in Indian mustard.

Key words: Genetic divergence, Indian mustard

Introduction

Indian mustard [Brassica juncea (L.) Czern & Coss] an important oilseed crop grown in north and northwest India is the second most important oilseeds crop after groundnut in India. To accomplish success in mustard improvement programme it is necessary to collect information on genetic diversity, as it provides the basis for a efficient selection of genotypes for hybridization. Many workers have long recognized the importance of genetic diversity in selection of parents for hybridization. (Murty and Arunachalam, 1966; Jagadev *et al.*, 1991; Mahto, 1996.).

Material and methods

Thirty-two genotypes of Indian mustard selected from the germplasm maintained at the Main Castor- Mustard Research Station, Gujarat Agricultural University, Sardarkrushinagar, were grown in Randomised Block Design with three replications during *rabi*, 2000-2001 at Sardarkrushinagar. Each replication consisted of single row of 3 m for each entry, with row-to-row and plant-to-plant spacing being 45 cm and 15 cm, respectively. The experimental area was fertilized at the rate of 50-50-00 Kg NPK/ha in the form of urea and diammonium phosphate. Other plant protection measures were taken and irrigation applied as per the recommendation for the crop.

Five competitive plants were randomly selected in each entry for recording observation on total number of branches (cm), number of siliquae/plant, number of seeds/siliqua, test weight (g), seed yield/plant (g) and oil content (%), However observations were recorded on plot basis for characters days to 50% flowering and days to maturity.

Following the analysis of variance the data were subjected to multivariate analysis of genetic divergence using Mahalanobis D^2 statistics (Mahalanobis, 1936). Grouping of entries was done by following Tocher's method. (Rao, 1952).

Results and discussion

The analysis of variance revealed considerable amount of variability for the nine traits studied. Suggesting ample scope to identify desirable genotypes. Based on the relative magnitude of D^2 values 32 genotypes were grouped into 6 different clusters. (Table. 1)

Grouping pattern showed no clear relationship between geographical diversity and genetical diversity. The cluster II followed by cluster III was the largest comprising nine and seven genotypes respectively. The result showed that geographical diversity was not necessarily a direct cause of genetic diversity. The geographical diversity has been disproved to be an index of genetic diversity in several crops (Mahto, 1996; Shalini *et al.*, 2000; Verma and Sachan, 2000). Frequent exchange of breeding materials from one place to another and further selection may also be responsible for distribution of gene complex over distant locations. Thus, it is more appropriate to select genotypes for hybridization based on genetic diversity rather than geographical diversity.

Table 1 The distribution of 32 genotypes of Indian mustard into different clusters on the basis of D^2 statistics

Cluster	Genotype	Source	Parentage	Number of genotypes
I	JMG-135	Hissar	--	6
	SKM-9585	S.K.Nagar	Selection from "valmi" GM 1	
	SKM-9803	S.K.Nagar	RSK-11 x RSK-33	
	SKM-9821	S.K.Nagar	RSK-16 x GM-1	
	SKM-9904	S.K.Nagar	RSK-11 x RSK -33	
	SKM-9936	S.K.Nagar	GM-1 x EC-287711	
II	Jawahar Mustard-1	Morena	Puisa Bold x L-6	9
	Lalpur-12	S.K.Nagar	Local selection	
	PCR-7	NRCM, Bharatpur	--	
	SKM-9033	S.K.Nagar	RSK-11 x Pusa Barani	
	SKM-9346	S.K.Nagar	(Pusa Bold x T -6342) x Pusa Bold.	
	SKM-9826	S.K.Nagar	SKM-85-5 x Varuna	
	SKM-9914	S.K.Nagar	RSK-16 x RH-9020	
	SKM-9941	S.K.Nagar	RH-30 x ZEM-1	
III	BIO-902	Pusa,New Delhi	Somoclonal Selection (Varuna)	7
	Kranti	Pantnagar	Pureline Selection from varuna (PR-15)	
	Krishna	Pantnagar	Selection from Varuna	
	RK-9402	Kanpur	--	
	Rohini	Kanpur	Yellow Sarson x Hyola-401	
	Vardhan	Kanpur	Culture of RK- 1467	
	Varuna	Kanpur	Selection from T-59 population	
IV	GM-1	S.K.Nagar	MR-71-3-2 x TM-4	2
	GM-2	S.K.Nagar	Local selection from Vedancha Village	
V	NDR-8501	Faizabad	--	6
	PBR-181,	Ludhiana	RLM-198 x Varuna	
	PM-67	Patan (Gujarat)	Selection from Local material	
	Pusa Bold	Pusa, New Delhi	Varuna x BJC-178	
	PYM-7	NRCM, Bharatpur	--	
	SKM-9232	S.K.Nagar	RSK-2 x Varuna	
VI	ZEM-1	Exotic	---	1

Table 2 Average Intra (Bold) and inter cluster distance D ($D=\sqrt{D^2}$)

Cluster	I	II	III	IV	V	VI
I	**2.64**	4.25	5.21	4.66	5.76	20.08
II	.	**4.48**	5.44	6.01	5.82	18.83
III			**5.15**	6.84	5.58	17.75
IV				**2.88**	7.14	21.88
V					**6.53**	**18.13**
VI						0

Table 3 Cluster means for different characters in Indian mustard

Cluster No.	No of Entries	Seed yield (g)	Days to 50% Flowering	Days to Maturity	Number of Branches	Plant Height (cm)	Number of siliquae/ plant	Number of seeds/ siliqua	Oil content (%)	1000 seed weight (g)
I	6	21	43	117	24	116	292	13	38	5.0
II	9	20	45	118	24	127	292	14	38	5.1
III	7	21	46	125	27	128	311	14	37	5.0
IV	2	27	44	113	32	117	355	15	39	5.1
V	6	20	45	123	27	131	327	17	37	5.0
VI	1	12	54	140	21	197	368	17	35	1.3

The intra cluster distance ranged from 0 to 6.53 (Table 2). The inter cluster distance (D) ranged from 21.9 to 4.3. Maximum inter cluster D-value was observed between cluster IV and VI (21.9).This further confirmed that geographic origin was not confirmed indicator of genetic diversity, Similar finding have also been reported by Murty and Arunachalam (1966); Mahto (1996); Shalini. et al., (2000) and Verma and Sachan (2000).

The average cluster means for 9 traits indicated that genotypes included in cluster VI was maximum divergent for all the traits studied (Table 3). Cluster IV recorded the highest mean value for seed yield/plant (27.2), number of branches/plant (32.4) and oil percentage (38.5%) with the minimum mean value for days to maturity (113). Cluster I recorded the lowest mean value for days to 50% flowering (42) and plant height (116). The maximum mean 1000 seed weight (5.1) was recorded for cluster II.

It was found that plant height contributed maximum to the total divergence (40.5%) followed by days to maturity (17.5) and branches/plant (14.3). Test weight having low contribution (12.5), whereas other traits showed very low contribution.

So, from the present study, the diverge clusters (I, IV and VI) hold good promise for various hybridization based breeding programmes, genotypes from these clusters can be used for obtaining high heterotic response and thus better segregants in Indian mustard.

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J. Oilseeds Res., **23**(2) : 159-160 (2006)

Genetic parameters and inter-relationship analysis in Indian mustard, *Brassica juncea* (L.) Czern & Coss

J.M. Patel, K.M. Patel, C.J. Patel and K.P. Prajapati

Main Castor and Mustard Research, S.D. Agricultural University, Sardarkrushinagar-385 506, Gujarat

(Received: August, 2005; Revised: December, 2005; Accepted: December, 2005)

Abstract

Study of 40 genotypes of Indian mustard for 13 different characters revealed considerable variability for all the characters under study. Close correspondence between GCV and PCV was obtained for test weight, seed yield per plant, number of siliquae per plant and days to 50% flowering. High heritability and high genetic advance was observed for days to 50% flowering, plant height and number of siliquae, whereas, seed yield per plant and test weight recorded high heritability with moderate genetic advance.

Key words: *Genetic variability, genetic advance,* heritability, Indian mustard

Introduction

Indian mustard is an important winter oilseeds crop grown in India. The knowledge of genetic parameters of variation, provides an idea about the extent of genetic improvement possible for different characters. Simultaneously, the knowledge of interrelationship of plant characters with seed yield and among themselves also help the breeders in improvement of a complex character like seed yield for which direct selection is not much effective. The present investigation was therefore, under taken to assess the interrelationship and genetic variability for some quantitative characters in a set of selected genotypes.

Material and methods

Forty genotypes of Indian mustard were grown in Randomized Block Design with three replications during *rabi*, 2002-2003, maintaining row to row and plant to plant distance of 45 cm and 15 cm, respectively. Recommended agronomic practices were followed. The observations on 13 quantitative traits were recorded in each plot on ten randomly selected plants from each replication. Genotypic and phenotypic variances were computed according to method suggested by Johnson *et al.* (1955). Heritability [H^2(bs) and genetic advance as per cent mean were calculated according to Allard (1960) and Johnson *et al.* (1955), respectively.

Results and discussion

The analysis of variance revealed significant differences among the genotypes for all the characters under study which indicated the presence of considerable amount of variability in the materials (Table 1). Better scope for improvement through selection existed for former characters and was confirmed through phenotypic and genotypic coefficient of variation. Genotypic and phenotypic coefficient of variation (GCV and PCV) were high for test weight, seed yield/plant, number of siliquae/plant and days to 50% flowering (Table 2). Similar results were also observed by Singh *et al.*(2003). Burton (1951) suggested that the genotypic coefficient of variation and heritability estimates give proper guideline for further selection.

Table 1 Analysis of variance (mean squares) for various characters in Indian mustard

Character	Replication	Genotype	Error
Degree of freedom	2	39	78
Days to 50% flowering	1.52	186.98**	1.47
Days to maturity	6.25	70.73**	9.64
Plant height	382.21	1875.18**	208.03
Length of main branch	97.83	304.79**	62.74
No. of primary branches/plant	3.10	1.27**	0.27
No. of secondary branches/plant	9.40	9.94**	3.64
No. of silique/plant	5007.20	14758.01**	2811.79
Length of siliqua	0.03	0.54	0.19
No. of seeds/siliqua	5.81	6.20*	2.00
Seed yield/plant	3.41	52.17**	6.02
1000 seed weight	0.016	3.36**	0.08
Oil content	1.49	5.17**	0.56
Harvest index	5.56	106.65**	41.87

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

High heritability observed for days to 50 % flowering, test weight, oil content, seed yield/plant, plant height and days to maturity, these characters can be improved through selection based on their phenotypes. These results were in conformity with Singh *et al.* (2003) for test weight, days to 50% flowering, days to maturity and seed yield/plant.

Table 2 Range, mean, genotypic, phenotypic, environmental variance, GCV, PCV, H^2(bs) and GA as per cent of mean for various characters in Indian mustard

Character	Range	Mean	Genotypic variance	Phenotypic variance	Environmental variance	GCV (%)	PCV (%)	H^2(bs) (%)	GA as % of mean
Days to 50% flowering	34-78	45.67	61.83	63.30	1.47	17.21	17.42	97.76	16.01
Days to maturity	114-137	124.91	20.36	30.00	9.64	3.61	4.39	67.86	3.78
Plant height (cm)	137.26-248.20	189.80	555.72	763.74	208.02	12.42	14.56	72.76	41.39
Length of main branch (cm)	53.60-101.60	85.84	80.68	143.42	62.74	10.46	13.95	56.25	13.86
No. of primary branches/plant	3.40-6.66	4.22	0.33	0.06	0.27	13.66	18.43	55.00	0.87
No. of secondary branches/plant	7.13-15.73	10.45	2.10	5.74	3.64	13.85	22.92	36.00	1.77
No. of siliquae/plant	230.60-537.66	360.05	3982.07	6793.86	2811.79	17.52	22.89	58.00	98.47
length of siliqua (cm)	4.18-5.82	5.20	0.11	0.30	0.19	6.49	10.72	36.00	1.07
No. of seeds/siliqua	10.96-18.06	13.46	1.39	3.39	2.00	8.98	13.67	26.00	0.40
Seed yield/plant (g)	9.63-30.40	20.88	15.06	21.40	6.02	18.58	22.08	71.00	6.75
1000-seed weight (g)	2.65-6.85	4.71	1.09	1.17	0.08	22.16	22.09	93.00	2.06
Oil content (%)	35.14-42.62	37.41	1.53	2.09	0.56	3.13	3.87	73.00	2.16
Harvest index(%)	14.12-43.29	32.83	21.59	63.45	41.86	14.15	24.26	34.00	5.57

Estimated genetic advance expressed as per cent of mean revealed relative differences among the quantitative characters studied. The traits like number of siliquae/plant and plant height has expressed high genetic advance as per cent of mean. Moderate genetic advance was recorded for days to 50% flowering and length of main branch and remaining all other characters showed low genetic advance. These results are in agreement with the findings of Singh *et al.* (2003) for days to 50% flowering and Mahala *et al.* (2003) for plant height and days to 50% flowering.

The higher estimates of heritability coupled with higher genetic advance for plant height and number of siliquae/plant indicating that heritability of trait is mainly due to additive effects and selection is effective for these traits. These results were in accordance with Ghosh and Gulati (2001) for days to maturity and Mahala *et al.* (2003) for plant height. High heritability coupled with medium genetic advance for seed yield/plant was indicative of both additive and non-additive gene action.

High genotypic coefficient of variation, high heritability and high genetic advances are helpful in making selection of superior genotypes. This study indicated that the selection on the basis of days to 50% flowering, plant height, test weight, seed yield/plant and number of siliquae/plant would be fruitful for development of elite genotypes of Indian mustard.

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J. Oilseeds Res., **23**(2) : 161-164 (2006)

Evaluation and characterisation of sunflower, *Helianthus annuus* L germplasm accessions

A. Vishnuvardhan Reddy and R. Nagaraja Reddy[1]

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP

(Received: August, 2004; Revised: July, 2005; Accepted: December, 2005)

Abstract

Germplasm accessions of sunflower (100) were evaluated for yield and yield components to study the extent of variation for different quantitative traits. The germplasm accessions were also characterized on the basis of qualitative traits. Highest phenotypic and genotypic coefficients of variation were recorded for seed yield/plant (84.9% and 79.4%, respectively) followed by seed filling, hundred seed weight, hull content, number of leaves/plant and oil per cent. High heritability was noticed for all the quantitative traits studied. High heritability coupled with high genetic advance over mean were recorded for seed filling (94.9% and 89.2%) and seed yield (56.2% and 86.3%) followed by hull content, oil content, plant height and hundred seed weight. Qualitative traits also showed wide variability among the accessions.

Key words: *Helianthus annuus*, characterization, genetic variability

Introduction

Sunflower is one of the important edible oilseed crops in the world. The crop is spreading to diverse agro-production situations, crossing climatic and geographic boundaries, which necessitated the development of more productive hybrids of diverse duration. Concerted breeding efforts are needed to meet this demand. The nature and magnitude of variability present in the germplasm has significant impact on the success of plant breeding. Furthermore, the assessment of heritable and non-heritable components of total variability will have immense value in the choice of the suitable breeding procedures. Characterization of germplasm lines is useful in identifying suitable lines and to avoid duplication. Being stable over generations and environments, the qualitative characters are reliable for characterization of germplasm. Hence, the current study was conducted to estimate the amount of genetic variability, heritability and genetic advance over mean for yield and yield components and to characterize the different germplasm accessions based on qualitative characters.

Materials and methods

The material for the present study comprised of 100 germplasm accessions (GMU-01 to GMU-100) of sunflower and two checks *viz.*, DRSF-108 and Morden. The experiment was conducted at Directorate of Oilseeds Research, Hyderabad during *kharif*, 2003. Each accession was sown in five rows of 3 m length each, with a spacing of 60 cm between rows and 30 cm between plants. The experiment was laid out in Randomized Block Design with two replications. In each accession, five plants were randomly selected and used for collection of data on yield and yield related characters *viz.*, leaf lamina length, leaf lamina width, petiole length, days to 50 per cent flowering, days to maturity, plant height, number of leaves/plant, head diameter, seed filling, 100 seed weight, seed yield/plant and oil content. The phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were computed and classified as suggested by Burton and Dewane (1953), heritability (h^2) as per Hanson *et al.* (1956) and expected genetic advance over mean (GAM) as suggested by Johnson *et al.* (1955).

The germplasm accessions were characterised into 12 qualitative characters using Anon. (1985) descriptors *viz.*, early plant vigour, leaf margin, leaf colour, stem and leaf pubescence, leaf shape, disc and ray floret colour, leaf base, head shape, head position and seed colour.

Results and discussion

The variation in the selected germplasm for all the 13 characters is evident from the significant mean squares (Table 1). Different parameters like range, phenotypic and genotypic variance, phenotypic and genotypic coefficients of variance, heritability estimates and predicted genetic advance over mean for the characters are presented in Table 2. The PCV and GCV found to the highest for seed yield/plant (84.9% and 79.4%, respectively) followed by seed filling (45.6% and 44.5%, respectively), 100 seed weight (29.7% and 20.5%), hull (22% and 20.2%), number of leaves/plant (30.5% and 10.0%) and oil (23.5% and 20.8%) indicating the presence of greater variability, which gives ample scope for improvement of these traits

[1] Research Associate

by simple selection. The high PCV and GCV observed for these traits is in conformation with earlier reports of Suma and Virupakshappa (1994). Moderate PCV and GCV have been observed for leaf lamina length, leaf lamina width, petiole length, plant height and head diameter and low PCV and GCV for days to 50% flowering and days to maturity. Low variability for these characters emphasizes the need for generating more variability. Low variability for these characters has also been reported by Alam *et al.* (1987).

High heritability has been noticed in respect of all the quantitative traits studied. High heritability coupled with high genetic advance over mean has been recorded for per cent seed filling (94.9 and 89.2) and seed yield (56.2 and 86.3) followed by hull per cent, oil percentage, plant height, 100-seed weight suggesting better scope for improvement of these characters through direct selection. Similar results were reported by Gangappa (1991) and Jayaramaiah *et al.* (1994). High heritability with moderate genetic advance has been observed for days to 50% flowering and maturity, low heritability with low genetic advance over mean for leaf lamina length, leaf lamina width, petiole length, head diameter and number of leaves/plant indicating greater influence of environment in the expression of these characters. Therefore, direct selection for improvement of these traits would be futile.

While characterizing the germplasm, it has been noticed that there has been wide variation for all the qualitative characters among the accessions. Out of one hundred accessions (Table 3), most accessions showed poor early plant vigour, high leaf serration, dark green leaves, dense pubescent stem, sparse pubescent leaves, cordate leaf shape, yellow disc floret and ray floret colour, auriculate leaf base, flat head shape, drooping head position and black seed colour. This is in conformation with earlier reports of Virupakshappa and Sindagi (1987).

The germplasm accession, GMU-17 recorded the longest leaf lamina length (29.8 cm) and the highest leaf lamina width (29.7 cm) and the accession GMU-32 (29.8 cm) and the highest leaf lamina width (29.7 cm) and the accession GMU-32 (21.0 cm) recorded the longest petiole length. The accessions GMU-91 and GMU-92 were early flowering types (42 days) whereas accessions GMU-63, GMU-64 and GMU-65 were late types (59 days). The accession, GMU-40 has recorded the lowest days to maturity (75 days), whereas, accessions GMU-85 and GMU-98 were late maturing types (97 days). These accessions can be used in breeding for earliness. The accessions GMU-43 found to be the tallest (177 cm) followed by GMU-65, whereas GMU-78 has a dwarf plant type (112 cm). Largest heads have been observed in GMU-04 (17 cm) and GMU-19 (17.2 cm), whereas smallest head size of 8.6 cm has been noticed in GMU-53 and GMU-96. The highest number of leaves has been observed in GMU-34 (41), whereas the least was in GMU-96 (14.4). The accession GMU-05 (82.1%) recorded highest seed filling which is followed by GMU-33 (81.5%) and the least in GMU-78 (4.8%). The accession GMU-16 recorded lowest oil (9.8%) and highest hundred seed weight (8.6 g) and hence could be a promising accession for confectionery purpose. Maximum oil per cent was observed in accession, GMU-20 (34.9%). The accession GMU-46 recorded lowest hull (19%), whereas, accession, GMU-14 recorded highest hull (65.1%). Maximum seed yield/plant was observed in accession GMU-72 (17.2 g), followed by GMU-34 (16 g), which can be used for breeding for high yielding varieties and hybrids.

Thus, it can be concluded that no germplasm accession is found to be good for all the quantitative characters. However, different accessions have been identified as promising for different traits as compared to the best check DRSF-108 or Morden (Table 4). Thus, a gene pool can be generated by constituting the germplasm lines of interest or by creating a broad based cross. Such material could be useful as a base population to develop promising populations and lines.

Table 1 *Analysis of variance for quantitative traits in sunflower*

Source	d.f.	Leaf lamina length	Leaf lamina width	Petiole length	Days to 50% flowering	Days to maturity	Plant height	Head diameter	No. of leaves	Seed filling (%)	Oil (%)	Hull (%)	100-seed weight	Seed yield/ plant
Genotypes	99	17.5**	17.5**	12.7**	47.8**	82.8**	608.9**	8.3**	57.6**	909.4**	54.7**	111.6**	3.3**	34.1**
Replication	1	0.6	3.1	9.5	0.02	8.00	34.3	2.4	0.1	5.5	0.6	45.3	2.5	5.7
Error	99	0.6	1.0	0.4	1.7	1.7	5.6	0.5	0.5	3.4	1.8	2.2	0.5	0.3
CV (P=0.05)		3.7	6.1	3.6	4.9	2.8	5.9	5.5	2.9	10.3	10.9	8.8	14.7	9.0

** = *Significant at 5% level*

Table 2 Range, mean, coefficients of variation, heritability and genetic advance for quantitative traits in sunflower germplasm

Character	Range	Mean	PV	GV	PCV (%)	GCV (%)	h^2	GAM
Leaf lamina length (cm)	18.0-29.8	22.7	13.8	1.5	15.3	5.0	10.7	3.4
Leaf lamina width (cm)	9.7-29.7	22.7	16.4	1.1	17.8	4.6	6.8	2.5
Petiole length (cm)	102-21.0	15.1	14.3	1.5	25.0	8.2	10.8	5.6
Days to 50% flowering	42-59	49.5	26.9	20.9	10.5	9.2	77.7	16.8
Days to maturity	75-97	85.2	44.4	38.1	7.8	7.3	86.5	13.9
Plant height (cm)	112-177	133.3	335.7	273.2	13.7	12.4	81.4	23.0
Head diameter (cm)	8.6-17.0	12.4	8.0	0.5	22.7	4.9	5.8	2.1
No. of leaves/plant	14.4-41.0	23.7	52.0	5.6	30.5	10.0	10.8	6.7
Seed filling (%)	4.9-82	47.3	466.6	442.8	45.6	44.5	94.9	89.2
Oil (%)	9.8-34.9	23.6	30.7	24.0	23.5	20.8	78.4	38.0
Hull (%)	19.0-65.1	35.3	60.6	50.9	22.0	20.2	84.0	38.2
100-seed weight	1.4-8.6	5.2	2.4	1.2	29.5	20.5	48.1	29.4
Seed yield/plant (g)	2.0-8.6	6.0	30.6	17.2	84.9	79.4	56.2	86.3

PV = Phenotypic variance; GV = Genotypic variance; h^2 = Heritability; GAM = Genetic Advance Over Mean

Table 3 Grouping of germplasm collections of sunflower on the basis of qualitative characters

S.No.	Character	No. of accessions
1.	**Early plant vigour**	
	Poor	69
	Good	15
	Very good	16
2.	**Leaf margin**	
	Entire	0
	Low serrate	9
	Medium serrate	39
	Highly serrate	52
3.	**Leaf colour**	
	Light green	31
	Green	28
	Dark green	41
4.	**Stem pubescence**	
	Glabrous	0
	Sparsely pubescent	27
	Moderately pubescent	9
	Densely pubescent	64
5.	**Leaf pubescence**	
	Glabrous	2
	Sparsely pubescent	75
	Moderately pubescent	4
	Densely pubescent	19
6.	**Leaf shape**	
	Lanceolate	2
	Triangular	30
	Cordate	64
	Rounded	5
7.	**Disc floret colour**	
	Yellow	88
	Purple	0
	Orange	12
8.	**Ray floret colour**	
	Yellow	100
	Pale yellow	0
	Red	0
9.	**Leaf base**	
	Acute	1
	Deltoid	1
	Cordate	31
	Auriculate	67
10.	**Head shape**	
	Concave	23
	Flat	76
	Convex	1
	Triangular	0
11.	**Head position**	
	Erect	0
	Intermediate	28
	Drooping	72
12.	**Seed colour**	
	White	1
	White with black strips	1
	Grey with black strips	0
	Grey with white strips	16
	Grey	1
	Brown	0
	Purple	3
	Purplish black	18
	Black with white strips	23
	Black	37

Table 4 Promising accessions of sunflower for different characters (over best check)

Character	Germplasm accessions
Days to 50% flowering (<45 days)	GMU-20, 62, 11, 74, 02, 06, 21, 33, 50, 59, 66, 76, 80, 82, 86, 94, 99, 05 and 09
Days to maturity (<80 days)	GMU-53, 62, 67, 15, 19, 10, 14, 21, 25, 30, 32, 37, 40, 42, 45, 46, 48, 52, 59, 76, 81, 82, 83, 84, 85, 91, 93, 94 and 95
>95 days	GMU-06, 47, 51, 58, 74, 77, 50 and 72
Plant height (>145 days)	GMU-81, 17, 99, 36, 77, 34, 58, 79, 07, 78, 75, 98, 72, 42, 43 and 48
No. of leaves/plant (>36)	GMU-42 and 75
100-seed weight (>6 g)	GMU-86, 87, 07, 14, 63, 65, 82, 10, 49, 77, 01, **15**, 17, 39, 47, 96, 13, **38, 95, 09, 81, 33, 19, 28, 42, 46**, 60, 66, 74, 16, 57, 61, 72, 75, 62, 18, 67, 27, 35 and 99
Oil per cent (>32.2%)	GMU-89, 70, 49 and 97
Hull per cent (<20%)	GMU-46, 18, 20, 61, 95, 70, 38, 53, 62, 52, 27, 50, **87**, 96, 23, 30, 100, 47, 83 and 86
Head diameter (<11.8 cm)	GMU-19, 40, 32, 69, 82, 13, 38, 53, 88, 95, 54, 85, **14**, 83, 36, 45, 90, 37, 64, 70, 17, **29, 39, 44, 49, 89**, 10, 12, 21, 30, 51, 62, 87, 01, 23, 34, 76, 03, 15, 22, 28, 63 and 79
>(14.2 cm)	GMU-92, 05, 07, 25, 52, 42, 27, 50, 56, 74, 96, 35, 80, 81, 02, 94, 99, 65, 41 and 66

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J. Oilseeds Res., **23**(2) : 165-167 (2006)

Analysis of genetic divergence in sunflower, *Helianthus annuus* L.

E. Ravi, M. Bharathi, A. Vishnuvardhan Reddy[1] and K. Madhavi Latha[2]

Department of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad-500 030, AP

(Received: October, 2005; Revised: May, 2006; Accepted: June, 2006)

Abstract

Sunflower genotypes (66) were evaluated for 13 yield and yield attributing characters to study the genetic diversity existing among them by using Mahalanobis D^2 statistics. The genotypes grouped into various clusters revealed that there was no relationship between geographical distribution and genetic diversity. Maximum inter-cluster distance was observed between cluster VIII and IV (27.33) while, lowest divergence was noticed between cluster I and VII (12.32). Among the 13 characters studied, seed set (%) under self-pollination contributed highest towards genetic divergence (36.64%) followed by total drymatter/plant (24.38%) and seed yield/plant (15.91%). Cluster IV exhibited highest means for plant height, head diameter, days to maturity, seed yield/plant, filled seeds/plant, harvest index and seed set per cent under open pollination. Cluster VIII exhibited lowest means for plant height, total drymatter/plant and seed set (%) under open pollination. The genotypes from cluster IV and VIII, which have high and low cluster means for the majority of the characters are suggested as parents for hybridization programme to achieve novel recombinants.

Key words: Genetic divergence, D^2, variability

Introduction

Genetic divergence among parents is essential since the crossing programme involving genetically diverse parents is likely to produce high heterotic effects and also more variability could be expected in the segregating generations. Genetic diversity between populations/ genotypes indicates the differences in gene frequencies. Multivariate analysis using Mahalanobis D^2 statistic (1936) is a valuable tool to study genetic divergence at intervarietal and sub-species level in classifying the crop plants. This has been successfully utilized in sunflower to classify the genotypes and determine their inter-relationships by many workers Marinkovic *et al.* (1992); Sankarapandian *et al.* (1996) and Teklewold *et al.* (2000). The present study was carried out to ascertain the nature and magnitude of genetic divergence among 66 sunflower genotypes.

Material and methods

A field experiment was conducted with 63 inbred lines in *rabi*, 2001 in a Randomized Block Design replicated thrice at Directorate of Oilseeds Research Farm, Hyderabad. The spacing adopted was 60 x 30 cm. Each genotype was sown in one row of 3.0 m length. Recommended agronomic practices were followed to raise a healthy crop. Observations were recorded on each entry on five randomly selected plants for yield and yield attributing characters *viz.*, plant height (cm), head diameter (cm), days to maturity, 100-seed weight (g), leaf area index (LAI) (Watson, 1952), total drymatter/plant (g) (TDM), filled seeds/plant, unfilled seeds/plant, seed yield/plant, harvest index (%), oil content (%) and seed set (%) under self-pollination and seed set (%) under open pollination. Genetic divergence was estimated by Mahalanobis D^2 statistic and the genotypes were grouped on the basis of minimum generalized distances using ward's minimum variance dendogram.

Results and discussion

The analysis of variance revealed significant differences among the genotypes for each character, indicating the existence of variability among the genotypes for the characters studied. Sixty three genotypes were grouped into nine clusters based on D^2 values such that the genotypes belonging to same cluster had on an average smaller D^2 values than those belonging to different clusters (Table 1). Out of 9 clusters formed, cluster I is the largest group with 12 genotypes, followed by cluster III and V with 9 genotypes each, while cluster VI had 8 genotypes, cluster II with 6 genotypes, cluster VIII had 7 genotypes, cluster VII with 5 genotypes, cluster IX had 4 genotypes and cluster IV had only 3 genotypes. The pattern of group constellations proved that significant amount of variability existed. It is interesting to note that 63 genotypes representing differences in their origin were grouped in the same cluster. This is an indication for the absence of relationship between genetic diversity and geographic diversity. Similar results have been reported

[1] Senior Scientist, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP; [2] Scientist, ICRISAT, Patancheru.

by Anand and Chandra (1980); Yadav *et al.* (1988) and Shankara Pandian *et al.* (1996).

The average intra and inter cluster distance (Table 2) revealed that the genetic diversity among the genotypes in cluster IV was minimum (6.242), followed by cluster VII (9.849). The maximum intra cluster distance (10.836) was observed in cluster VI. Selection with this cluster might be exercised on the highest mean for the desirable traits.

Table 1 Distribution of 63 genotypes of sunflower in different clusters

Cluster No.	No. of genotypes	Genotype
I	12	GP-691, RGP-267-3, RGP-98-2-2, Acc. No. 186, 222, 294, 164, 109, IB-28, GP-801, 493, 1063
II	6	GP-188, 925, RGP-239-1, Acc.No. 217, 153, NDSI-2-2-4-3
III	9	GP-1949, GP-763, Acc.No. 130, 192, 333, 2116, GP-763, RGP-280-1, NDSI-4, RGP-192-2-1-2
IV	3	GP-761, Acc. No. 277, 116
V	9	GP-698, 536, 373, 580, 2068, 211, RGP-3-11-3, 2-49-2, Acc. No. 159
VI	8	DRM-1-1, 65-4, R-273, X-15-NB-5, HAR-3, LIB-02M-3, Acc.No. 1147-1, RGP-257-1
VII	5	NDSI-7-3-1-1, Acc.Nos. 110, 200-1, 238, 1266
VIII	7	DRM-13-1, 128-2, 60-4, R-856, X-15-NB-10, NDSI-7-1-2-4, LIB-02M-4
IX	4	Acc. Nos. 356, 88-9, 88-2, GP-1969

The relative divergence of each cluster from other clusters (inter cluster divergence) indicated high order of divergence between cluster VIII and IV (27.33) followed by cluster IX and IV 26.77, IX and V (22.74). Selection of parents from such clusters for hybridization programme would help to achieve novel recombinants. Hybridization between genetically distant genotypes to generate promising breeding material has been suggested by Shankarapandian *et al.* (1996). The hybridization between the genotypes falling in the most distant clusters i.e., VIII (DRM 13-1) and IV (GP-761) should result into maximum hybrid vigour and eventually may give rise desirable recombinants.

The contribution of individual characters towards the divergence (Table 3) indicated that seed set per cent under self-pollination contributed highest towards genetic divergence (36.64) followed by TDM/plant (24.38) seed yield/plant (15.92) plant height (7.65) and head diameter (4.10) towards total genetic divergence. The remaining characters, days to maturity, harvest index, oil per cent, filled seeds/plant, leaf area index and seed set per cent under open pollination showed negligible contribution. Thus, five characters viz., seed set (%) under self-pollination, total drymatter/plant, seed yield/plant, plant height and head diameter were important since they together contributed 88.58% towards total divergence. In sunflower, Narsaiah (1995) reported that, seed yield and plant height are the important contributing factors.

There was a wide range of variation in the cluster mean values for most of the characters under study (Table 4). Cluster IV had highest mean values for plant height, head diameter, days to maturity, seed yield/plant, filled seeds/plant, harvest index, seed set per cent under SP, seed set per cent under OP. Cluster III recorded highest 100 seed weight and total drymatter/plant. Cluster VIII exhibited lowest means for plant height, total drymatter/plant and seed set per cent under open pollination.

Table 2 Average intra and inter cluster distance (D^2 values)

Cluster	1 cluster	2 cluster	3 cluster	4 cluster	5 cluster	6 cluster	7 cluster	8 cluster	9 cluster
1 cluster	10.041	12.857(M)	13.848(M)	17.449(H)	14.408(M)	15.976(H)	12.320(M)	16.570(H)	16.107(H)
2 cluster		10.696	16.127(H)	22.268(H)	19.212(H)	18.667(H)	14.931(M)	13.692(M)	13.828(M)
3 cluster			10.328	15.127(H)	15.410(H)	20.502(H)	15.835(H)	22.430(H)	20.249(H)
4 cluster				6.242	12.646(M)	20.710(H)	17.551(H)	27.332(H)	26.778(H)
5 cluster					10.567	15.433(H)	12.824(M)	22.666(H)	22.742(H)
6 cluster						10.836	12.539(M)	17.550(H)	21.467(H)
7 cluster							9.849	16.675(H)	18.817(H)
9 cluster								10.258	13.382(M)
9 cluster									10.731

H=Highly divergent (above 15); M=Moderately divergent (10-15)

Table 3 Contribution of different characters towards genetic divergence (D^2) in 66 genotypes of sunflower

Character	Times ranked first	% contribution towards divergence
Plant height	164	7.65
Head diameter	88	4.10
Days to maturity	47	2.19
100-seed weight	88	4.10
Leaf area index	9	0.42
Total drymatter/plant	523	24.38
Seed yield/plant	341	15.90
Filled seeds/plant	21	0.98
Unfilled seeds/plant	0	0.00
Harvest index	42	1.96
Oil content	34	1.59
Seed set (%) under self-pollination	786	36.64
Seed set (%) under open pollination	2	0.09

Crosses among diverse parents are likely to yield desirable combinations. Therefore, a crossing programme should be initiated between the genotypes belonging to different clusters. The greater the distance between two clusters, the wider the genetic diversity among the parents to be included in hybridization programme. Parents combining high yield potential with wide genetic diversity are likely to yield superior segregants within short period. Based on these facts, the genotypes, GP-761, Acc. No. 277 and 116 forming cluster IV and the genotypes GP-1949, GP-763, Jwala-Mukhi, Acc. No. 192 and 333 of cluster III are expected to give promising seed yield segregants in segregating generations as these genotypes were found to possess higher cluster mean values for desirable seed yield contributing characters and occupy different clusters. The genotypes with high mean value from any cluster can either straight away be used for adoption or can be used in hybridization for yield improvement.

Table 4 Mean of cluster from 66 genotypes of sunflower for 13 characters

	Plant height (cm)	Head diameter (cm)	Days to maturity	100-seed weight (g)	Leaf area index	Total drymatter/ plant (g)	Seed yield/ plant (g)	Filled seeds/ plant	Unfilled seeds/ plant	Harvest index (%)	Oil content (%)	Seed set (%) (SP)	Seed set (%) (OP)
1 Cluster	135.033	14.158	88.472	5.921	2.436	28.016	93.581	434.917	94.861	24.845	39.402	43.546	82.224
2 Cluster	113.138	11.807	81.190	6.238	2.656	23.571	107.748	344.286	132.714	18.108	38.282	30.090	73.040
3 Cluster	135.097	13.928	86.485	6.767	2.905	35.858	174.348	523.364	89.576	17.098	39.490	51.194	84.269
4 Cluster	145.178	16.789	89.667	5.997	3.088	57.030	135.678	915.000	69.333	29.601	39.281	67.471	92.577
5 Cluster	139.385	14.741	85.000	5.522	3.310	37.012	98.359	683.518	71.519	27.754	39.723	67.723	83.841
6 Cluster	101.054	14.029	86.625	3.404	2.404	20.586	68.817	597.250	66.167	23.251	35.457	64.029	88.564
7 Cluster	110.293	10.900	85.000	5.794	2.215	26.769	82.413	455.267	77.267	25.495	38.206	57.550	85.180
8 Cluster	98.824	9.431	85.190	3.701	2.377	9.880	63.600	229.762	96.857	14.794	37.252	29.667	71.220
9 Cluster	144.692	9.125	85.083	4.280	2.947	7.745	95.800	148.167	85.333	8.390	39.139	24.682	72.144

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J. Oilseeds Res., 23(2) : 168-170 (2006)

Combining ability studies in sunflower, *Helianthus annuus* L.

E. Pavani, M. Bharathi, A. Vishnuvardhan Reddy[1] and K. Madhavi Latha[2]

Department of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad-500 030, AP

(Received: December, 2005; Revised: May, 2006; Accepted: June, 2006)

Abstract

A line x tester set of 56 F_1s involving four cytoplasmic male sterile lines belonging to two different sources of cytoplasm and 14 common restorer lines along with parents were studied to estimate combining ability. The results indicated the importance of non-additive gene effects in the inheritance of all the 11 traits understudy. In general, the female parents CMS 7-1 and DCMS 42 and male parents DSI 724, DSI 729 were found to be good general combiners for most of the traits. The cross combinations DCMS 41 x DSI 753, DCMS 42 x DSI 716 and DCMS 41 x DSI 716 were found to be promising for most of the important agronomic characters including seed yield and oil yield/plant.

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

Introduction

Sunflower, *Helianthus annuus* L. offers scope for commercial exploitation of heterosis utilizing cyto restorer system. To initiate the hybrid breeding programme evaluation of inbred lines for combining ability is important. Such studies can be usefully exploited in the development of suitable breeding methodology for the improvement of different characters. In the present investigation combining ability of four lines and 14 testers has been studied in sunflower.

Material and methods

The material comprised of 56 sunflower hybrids developed from four CMS lines belonging to the different sources of cytoplasm, *viz.*, CMS 7-1 and CMS 335 belonging to PET-1 (*Helianthus petiolaris*) source and DCMS 41, DCMS 42 belonging to ARG (*Helianthus agrophyllus*) source were used as female parents and 14 restorer lines *viz.*, DSI 680, 686, 693, 695, 701, 716, 724, 725, 728, 729, 732, 736, 743 and 753. The hybrids along with parents were sown in RBD with three replications during *rabi*, 2003-04 at DOR, Rajendranagar, Hyderabad. The data were recorded for days to 50% flowering, days to maturity, plant height, stem diameter, head diameter, number of filled seeds/head, number of unfilled seeds/head, 100-seed weight, oil content, seed yield/plant and oil yield/plant. The combining ability analysis was carried out following modal proposed by Kempthorne (1957).

Results and discussion

The analysis of variance (Table 1) for 11 characters revealed significant differences between the genotypes, indicating wide diversity in the material. Mean squares for parents and crosses were also found to be significant for all the traits. The significance of variance due to parents vs F_1s suggested presence of heterosis in F_1s for the economic trait, oil yield/plant.

The mean sum of squares due to crosses were partitioned into lines, testers and interactions. The lines were found to be significant for days to maturity, stem diameter, number of filled seeds/head and seed yield/plant, the testers also showed significant mean sum of squares for all the above traits and also for oil yield/plant. The interaction mean sum of squares were found to be significant for all the characters. The variance component due to specific combining ability (*sca*) was greater in magnitude than that of general combining ability (*gca*) (Table 2) for all the characters indicating predominance of non-additive type of gene action which is in agreement with Radhika *et al.* (2001).

A perusal of *gca* effects of 18 parents (4 lines and 14 testers) for 11 traits indicated that the line CMS 7-1 was good general combiner for early flowering early maturity, dwarfness and less number of unfilled seeds/head by exhibiting significant *gca* effects in negative direction and is also found to be good general combiner for stem diameter, 100-seed weight, seed yield/plant and oil yield/plant by exhibiting significant *gca* effects in positive direction. The line DCMS 42 was found to be good general combiner for important traits like number of filled seeds/head, seed yield and oil yield. While the line CMS 335 was characterized by late maturity and also possessed favourable alleles for tallness, oil content, number of filled seeds/head by recording *gca* effects in the positive direction. The line DCMS 41 was poor combiner for stem diameter, number of filled seeds/head, number of unfilled seed/head, 100-seed weight, seed yield and oil yield by showing lowest *gca* effects.

[1] Senior Scientist, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, A.P.; [2] Scientist, ICRISAT, Patancheru

Among testers, DSI 743 and DSI 729 were good general combiner for majority of the traits i.e., days to 50% flowering, early maturity, head diameter, number of filled seeds/head, 100-seed weight, seed yield and oil yield by showing significant *gca* effects. For economic traits like seed yield and oil yield testers DSI 724, 743, 736, 729, 732, 716 and 686 were found to possess favourable alleles by showing significant *gca* effects (Table 3).

It can be concluded that in lines CMS 7-1 and in testers DSI 743 and DSI 729 possessed favourable alleles for most of the traits hence use of these parents in future breeding programmes is advised.

Setty and Singh (1977) observed that *gca* for yield was related to *gca* for one or more yield components which was in conformity with the present study. The parents which were good general combiners for economic traits may be extensively used in hybridization programme.

The sca effects showed that no single cross showed maximum *sca* effects for all the characters. The crosses DCMS 42 x DSI 686, DCMS 42 x DSI 724, CMS 7-1 x DSI 743, DCMS 41 x DSI 753 exhibited maximum *sca* effects for the characters like for days to 50 per cent flowering, plant height, 100-seed weight, number of filled seeds/capitulum, oil content, seed yield/plant and oil yield/plant (Table 4).

Table 1 Analysis of variance for combining ability for different characters

Source	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No. of filled seeds/ head	No. of unfilled seeds/head	100-seed weight (g)	Oil content (%)	Seed yield/ plant (g)	Oil yield/ plant (g)
Replications	2	4.07	18.49**	40.76**	0.01	0.09	6093.8*	18.40	0.09	2.00	7.153	0.73
Treatments	73	36.46**	40.96**	1015.23**	0.16**	7.74**	73248.6**	6365.71**	2.24**	55.81**	189.63**	19.69**
Parents	17	19.58**	14.68**	1766.68**	0.16**	17.52**	27968.85**	6252.64**	1.69**	51.70**	98.18**	8.45**
Parents vs. Crosses	1	5.84	2.02	13593.46**	0.31**	5.59**	10.77	15171.61**	0.25	0.02	8.47	5.33**
Crosses	55	42.23**	49.79**	354.27**	0.16**	4.76**	88575.84*	6240.56**	2.45**	58.09**	221.1**	24.89**
Lines	3	62.05	358.30**	1109.69	0.52**	4.50	79786.16**	2284.31	0.83	77.70	619.4**	34.63
Testers	13	44.70	82.40**	577.64	0.25*	5.36	151300.92*	7139.17	2.678	40.56	368.46*	52.36**
L x T	39	39.88**	15.19**	503.76**	0.10**	4.57**	68373.55**	6245.34**	2.49**	62.41**	141.46**	14.99**
Error	146	4.09	3.70	69.03	0.00	0.53	1572.35	166.95	0.35	6.04	3.69	0.30

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

Table 2 Estimates of general and specific combining ability variance, proportionate gene action and degree of dominance

Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No. of filled seeds/ head	No. of unfilled seeds/head	100-seed weight (g)	Oil content (%)	Seed yield/ plant (g)	Oil yield/ plant (g)
σ^2 *gca*	0.028	0.421	0.615	0.007	1.002	246.625	10.058	0.006	0.065	0.971	0.120
σ^2 *sca*	11.928	3.288	144.908	0.032	1.346	22257.0	2026.13	0.715	18.787	45.923	4.894
σ^2 *gca* / σ^2 *sca*	0.002	0.128	0.004	0.218	0.744	0.011	0.0496	0.008	0.003	0.021	0.025
Degree of dominance $\sqrt{\sigma^2 sca / 2\sigma^2 gca}$	14.59	1.976	10.845	1.011	0.820	0.717	10.036	7.72	12.02	4.860	4.515

Table 3 Estimates of general combining ability (*gca*) effects for lines and testers for different characters

Source	Days to 50% flowering	Days to maturity	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No. of filled seeds/ head	No. of unfilled seeds/head	100-seed weight (g)	Oil content (%)	Seed yield/ plant (g)	Oil yield/ plant (g)
Parents											
Lines											
CMS 335	1.82**	4.05**	7.47**	0.07**	-0.44**	20.89**	3.56	-0.12	1.51**	-5.41**	-1.21**
CMS 7-1	-0.68*	-0.02	-3.89**	0.01**	-0.04	-24.62**	-7.55**	0.19*	-0.63	2.07**	0.85**
DCMS 41	-0.54	-1.30**	-2.76*	-0.06**	0.30**	-46.35**	8.53**	0.02	0.67	0.06	-0.15
DCMS 42	-0.61	-2.73**	-0.82	-0.13**	0.19	50.08**	-4.55**	-0.09	-1.56**	3.28**	0.50**
SE_i	**0.31**	**0.29**	**1.28**	**0.00**	**0.11**	**6.11**	**1.99**	**0.09**	**0.37**	**0.29**	**0.08**
Testers											
DSI 673	0.57	6.80**	-1.76	-0.19**	-1.22**	-132.9**	-31.31**	-0.42*	-4.68**	-9.78**	-3.24**
DSI 686	1.07	-1.70**	3.03	-0.04*	-0.32	14.88	26.39**	-0.17	-0.25	4.60**	1.91**
DSI 680	2.32**	-0.70	-9.54**	0.03	-0.18	59.84**	-23.51**	0.15	0.57	0.35	0.93**
DSI 701	2.82**	1.55**	-0.56	0.14**	-1.04**	-45.13**	-7.31	-0.45**	-0.05	-3.07**	-1.37**
DSI 695	-2.18**	1.05	-7.81**	-0.23**	0.07	-26.69**	-23.76**	0.09	-0.53	-1.01	0.07
DSI 716	2.82**	-2.70**	4.50	-0.06**	-0.28	-33.00**	-13.80**	-0.76**	1.20	2.86**	2.13**
DSI 725	-2.18**	-1.95**	-4.36	-0.08**	0.82**	-76.53**	1.93	0.54**	-0.63	-0.81	-0.78**
DSI 732	-0.93	-1.95**	9.55**	0.28**	-0.01	81.05**	-17.49**	-0.10	-0.93	3.71**	0.83**
DSI 729	-2.43**	-2.45**	1.48	0.00	0.90**	76.40**	18.20**	0.95**	0.40	4.93**	1.86**
DSI 736	0.07	0.80	9.19**	0.03	0.12	147.21**	36.79**	-0.09	2.40**	1.44**	0.59**
DSI 743	-1.68**	-2.45**	-3.20	0.08**	1.22**	74.16**	48.17**	0.66**	1.37	5.76**	2.26**
DSI 728	-0.18	2.05**	11.85**	-0.08**	-0.19	-88.20**	7.56*	-0.25	1.85**	-8.76**	-3.64**
DSI 753	-1.93**	2.05**	-9.12**	-0.12**	0.07	-230.50**	-4.44	0.20	-2.28**	-7.63**	-3.09**
DSI 724	2.32**	-0.45	-3.22	0.22**	0.05	179.50**	-17.42**	-0.36*	1.52*	7.39**	1.52
SE_j	**0.58**	**0.55**	**2.39**	**0.01**	**0.21**	**11.44**	**3.73**	**0.17**	**0.70**	**0.55**	**0.16**

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

Table 4 Promising cross combinations for different characters based on *sca* effects

Character	Promising cross combinations
Days to 50% flowering	DCMS 41 x DSI 680 (-646**); DCMS 42 x DSI 724 (-6.39**); DCMS 42 x DSI 686 (-5.46**); DCMS 41 x 701 (-4.46**)
Days to maturity	CMS 335 x DSI 725 (-6.05**); CMS 335 x DSI 673 (-3.80**); DCMS 42 x DSI 695 (-3.27**); DCMS 41 x DSI 716 (-2.95**)
Plant height	CMS 335 x DSI 728 (-27.30**); DCMS 42 x DSI 686 (-21.19**)
Stem diameter	CMS 335 x DSI 728 (0.50**); DCMS 41 x DSI 743 (0.24**)
Head diameter	CMS 7-1 x DSI 728 (2.25**); DCMS 41 x DSI 736 (2.23**)
No. of filled seeds/head	CMS 7-1 x DSI 743 (305.78**); CMS 335 x DSI 732 (263.42**)
No. of unfilled seeds/head	DCMS 41 x DSI 724 (-106.85**); DCMS 42 x DSI 686 (-85.18**)
100-seed weight	DCMS 42 x DSI 724 (2.16**); DCMS 41 x DSI 673 (1.65**)
Oil content	DCMS 42 x DSI 724 (9.16**); CMS 7-1 x DSI 680 (7.08**)
Seed yield/plant	DCMS 41 x DSI 753 (17.39**); DCMS 42 x DSI 716 (9.19**); CMS 7-1 x DSI 743 (9.07**)
Oil yield/plant	DCMS 41 x DSI 753 (4.72**); DCMS 41 x DSI 716 (3.80**)

For all the 11 traits under study, the crosses with significant *sca* effects in the desirable direction involved parents with high x high or high x low or low x low *gca* effects, indicating high performance of these crosses due to additive, dominance and epistatic gene interaction. The ideal cross combination to be exploited is one, where high magnitude of *sca* is present in addition to high *gca* in both or atleast in one of the parents. Identification of heterotic crosses involving high x low *gca* cross combinations as revealed in the present study were earlier reported by Kadkol *et al.* (1984); Limbore *et al.* (1997) and Singh *et al.* (1999). In addition, crosses with high *sca* effects involving parents with high x high *gca* effects were also reported by Limbore *et al.* (1997), low x low by Kadkol *et al.* (1984) and Giriraj *et al.* (1987).

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J. Oilseeds Res., **23(2)** : 171-173 (2006)

Genetic analysis of quantitative traits in sesame, *Sesamum indicum* L.

K.P. Prajapati, K.M. Patel, B.H. Prajapati and C.J. Patel

Main Castor and Mustard Research, S.D. Agricultural University, Sardarkrushinagar-385 506, Gujarat

(Received: March, 2005; Revised: October, 2005; Accepted: December, 2005)

Abstract

An investigation carried out at Main Castor and Mustard Research Station, Gujarat Agricultural University, Sardarkrushinagar, Gujarat to assess the nature and magnitude of components of variation by employing 10 x 10 half diallel mating design in sesame. The variance due to specific combining ability was predominant for days to maturity, plant height, number of capsules/plant, capsule length, seeds/capsule and seed yield/plant. While, the variance due to general combining ability (gca) was predominant for days to 50% flowering, number of branches/plant, 1000-seed weight and oil content. Sesame cultivars PT 64, TMV 3 and AT 103 were best general combiners for seed yield and its major components. The hybrid, TMV 3 x C 1013 emerged as the best specific combiner for seed yield and its components.

Key words: Genetic analysis, components of variance, sesame

Introduction

Sesame (*Sesamum indicum* L.) is the oldest oilseeds known and used by man (Weiss, 1971). The crop has a large diversity in cultivars and cultural systems in India. Sesame crop is grown throughout the country and round the year with an annual production of about 7.9 lakh tones (Directorate of Economics and Statistics, 2002). India is the largest producer and exporter of sesame in the world. However, the increase in productivity of sesame in India is not so impressive as compared to other sesame growing countries of the world. The heterosis in sesame has not been exploited by developing high yielding heterotic hybrids to increase productivity. It is essential to choose of suitable parents for use in hybridization programme for assessing their genetic value. Therefore, the present investigation was carried to evaluate 10 genotypes of sesame for their combining ability.

Material and methods

A half diallel set was made using ten sesame genotypes *viz.*; AT 103, GT 1, PT 64, PT 65, Mrug 1, TC 25, Pb Til.1, Vinayak, TMV 3 and C 1013 during *kharif*, 2001. The resultant 45 hybrids along with ten parents were evaluated in Completely Randomized Block Design with three replications at the main castor and mustard research station, Gujarat Agricultural University, Sardarkrushinagar, Gujarat during *kharif*, 2002 with 45 x 15 cm spacing. The observations were recorded on five randomly selected plants of each genotype in each replication for ten characters such as days to 50% flowering, days to maturity, plant height, number of branches/plant, number of capsules/plant, capsule length, number of seeds/capsule, 1000- seed weight, oil content and seed yield/plant. The data were analyzed for combining ability using Griffing (1956), Model 1 and Method 2.

Results and discussion

There were highly significant variances for both *gca* and *sca* in the present test material (Table 1). The ratio of *gca* to *sca* variance was less than unity for seed yield/plant, number of capsules/plant, plant height, capsule length, seeds/capsule and days to maturity. This indicated that non-additive type of gene actions were primarily involved in the expression of these traits. The characters, *viz.*, days to 50% flowering, number of branches per plant, 1000-seed weight and oil content were governed by preponderance of additive gene action due to variance ratio observed more than unity.

Nature and magnitude of combining ability effects helps in identifying superior parents and their utilization in further breeding programme. The close examination of *gca* effects of the parents revealed that, none of the parent was found to be consistently good general combiner for all the characters (Table 2). However, the parents, AT 103, PT 64 and TMV 3 were good general combiners for seed yield and majority of its components. Among these, PT 64 was found to be best general combiner for seed yield/plant, number of capsules/plant, whereas, it was also good combiner for capsule length and seeds/capsule, 1000-seed weight and oil content. Parent, TMV 3 had positive significant *gca* effects for seed yield, number of branches/plant, number of capsules/plant and oil content, likewise, it was the best parent for number of branches/plant. Parent AT 103 recorded significant highest *gca* effects in desired direction for capsule length, seeds/capsule and days to flowering and maturity and it

was also good combiner for seed yield/plant, 1000-seed weight and dwarf plant type. Therefore, above parents were noted as good source of favorable genes for increasing seed yield. It is evident from these results that, high *gca* effects for seed yield/plant in parents PT 64, TMV 3 and AT 103 were mainly due to direct yield contributing characters. Therefore, it would be worthwhile to use above parental lines in hybridization programme.

Among the forty five crosses, the best specific combinations were different for different characters (Table 2). The crosses, Vinayak x TMV 3, AT 103 x PT 65 and AT 103 x GT 1 showed highly significant negative *sca* effects for days to 50% flowering and the crosses Mrug 1 x Vinayak, AT 103 x PT 64 and AT 103 x TMV 3 showed highly significant negative *sca* effects for days to maturity. These crosses can be used to isolate early flowering and maturity segregants in later generations, respectively. Likewise, the hybrid AT 103 x TMV 3 was the best specific combination for dwarf plant type and capsule length, it was also good combination for number of branches/ plant, seeds/capsule and 1000-seed weight. The crosses *viz.*; TMV 3 x C 1013, GT 1 x Pb Til 1 and AT 103 x Vinayak showed highly significant positive *sca* effects for seed yield and its contributing traits. These crosses can be used for isolation of transgressive segregants for seed yield.

It was also observed for most of the characters, the parents exhibiting high mean performance had manifested high general combining ability effects. Krishnaiah *et al.* (2003) also noted a close association between mean performance and general combining ability effects. On the basis of *per se* performance and combining ability, the most promising parents were PT 64, TMV 3 and AT 103. However the crosses with high mean did not posses high *sca* effects for all the characters except seed yield/plant suggesting that selection of good general combiners only on the basis of mean performance may not always be reliable.

The crosses with high *sca* effects did not always had parents with high *gca* effects. The crosses TMV 3 x C 1013, GT 1 x Pb.Til 1 and AT 103 x Vinayak expressed high significant *sca* effects in desired direction for seed yield, resulted from good x poor, average x poor and good x poor parent, respectively. A comparative study of crosses on the basis of *per se* performance and *sca* effects revealed that the most of the crosses, which produced maximum seed yield had at least one parent as good combiner for seed yield. This supports the importance of both additive and non-additive genetic variance in controlling yield and its components.

An overall view of the results suggested that genetically diverse parents with good *per se* performance and good combining ability should be selected for breeding programme aimed at improvement of sesame varieties. Like wise, the crosses exhibiting high specific combining ability effects for various traits suggested that the possibilities of an improvement of such traits by selection and hybridization from the desirable recombinants in the segreganting generations.

Table 1 Analysis of variance for combining ability in 10 x 10 half diallel crosses of sesame

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height	No. of branches/ plant	No. of capsules/ plant	Capsule length	Seeds/ capsule	1000-seed weight	Oil content (%)	Seed yield/ plant
General combining ability (*gca*)	9	34.62**	8.61**	372.27**	5.24**	277.91**	0.18**	74.99**	0.39**	8.87**	38.31**
Specific combining ability (*sca*)	45	2.24**	1.43**	54.16**	0.36**	40.95**	0.03**	11.83**	0.03**	1.08**	8.92**
Error	108	0.64	0.65	22.75	0.11	5.57	0.01	5.19	0.01	0.59	0.93
σ^2 *gca*	-	2.83	0.66	29.13	0.43	22.70	0.01	5.82	0.03	0.69	3.13
σ^2 *sca*	-	1.60	0.77	31.42	0.26	35.38	0.02	6.64	0.03	0.49	7.99
σ^2 *gca* / σ^2 *sca*	-	1.77	0.86	0.93	1.66	0.64	0.75	0.88	1.27	1.41	0.39

** = Significant at P=0.01 level

Table 2 Correspondence of mean performance of three best general combiners F_1s and the best specific cross combinations in desired direction for different traits of sesame

Character	Best parents	Best general combiner	Best F_1s	Best cross combinations
Days to 50% flowering	AT 103 GT 1 Pb. Til 1	AT 103 Pb. Til 1 TC 25	At 103 x GT 1 AT 103 x Pb. Til 1 TC 25 x Pb. Til 1	Vinayak x TMV 3 AT 103 x PT 65 AT 103 x GT 1
Days to maturity	AT 103 GT 1 C 1013	AT 103 GT 1 Pb. Til 1	At 103 x Pb. Til 1 At 103 x PT 64 GT 1 x Pb. Til 1	Mrug 1 x Vinayak AT 103 x PT 64 AT 103 x TMV 3
Plant height	C 1013 GT 1 AT 103	GT 1 AT 103 Pb. Til 1	AT 103 x GT 1 AT 103 x TMV 3 AT 103 x PT 65	AT 103 x TMV 3 PT 65 x Mrug 1 -
No. of branches/plant	TMV 3 C 1013 Vinayak	TMV 3 C 1013 Vinayak	TMV 3 x C 1013 GT 1 x TMV 3 AT 103 x TMV 3	PT 64 x C 1013 AT 103 x TMV 3 GT 1 x TMV 3
No. of capsules/plant	TMV 3 GT 1 AT 103	PT 64 TMV 3 GT 1	TMV 3 x C 1013 GT 1 x TMV 3 GT 1 x Pb. Til 1	GT 1 x Pb. Til 1 TMV 3 x C 1013 PT 64 x PT 65
Capsule length	AT 103 PT 64 GT 1	AT 103 PT 64 -	PT 64 x TC 25 AT 103 x PT 64 AT 103 x TC 25	AT 103 x TMV 3 GT 1 x TMV 3 PT 64 x Pb. Til 1
Seeds/capsule	AT 103 PT 64 GT 1	AT 103 PT 64 GT 1	AT 103 x PT 64 AT 103 x GT 1 AT 103 x TC 25	GT 1 x TMV 3 PT 64 x Mrug 1 AT 103 x TMV 3
1000-seed weight	PT 64 TC 25 AT 103	PT 64 AT 103 TC 25	AT 103 x PT 64 PT 65 x Pb. Til 1 PT 64 x TC 25	PT 64 x C 1013 AT 103 x TMV 3 Mrug 1 x Pb. Til 1
Oil content	PT 64 TMV 3 PT 65	PT 64 TMV 3 PT 65	TMV 3 x C 1013 PT 64 x PT 65 PT 64 x TMV 3	Pb. Til 1 x C 1013 TMV 3 x C 1013 GT 1 x Pb. Til 1
Seed yield/plant	TMV 3 PT 65 PT 64	PT 64 TMV 3 AT 103	TMV 3 x C 1013 PT 64 x Pb. Til 1 PT 64 x TC 25	TMV 3 x C 1013 GT 1 x Pb. Til 1 AT 103 x Vinayak

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J. Oilseeds Res., 23(2) : 174-177 (2006)

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

C. Lavanya, P.V. Ramana Rao[1] and V. Venkata Gopinath[1]

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP

(Received: November, 2005; Revised: March, 2006; Accepted: June, 2006)

Abstract

Twenty five castor hybrids generated in a line x tester (5 pistillate lines x 5 male parents) design were studied along with parents for heterosis and combining ability of seed yield and yield components. Estimates of variance due to GCA and SCA indicated predominant additive gene action for number of nodes to secondary raceme (S_1), hundred seed weight and seed yield while non additive gene action was predominant for number of nodes to primary, plant height, total spike length, effective spike length, effective spikes/plant and number of capsules. Among female parents, DPC 9 and DPC 10 were good general combiners for number of nodes to primary raceme, secondary racemes (S_1,S_2) and hundred seed weight. DPC 10 and M 584 were good combiners for seed yield. Among male parents RG 47, RG 297, RG 2445 were good combiners for number of nodes to primary, secondary S_1 and S_2 racemes. The parent RG 47 was also a good combiner for hundred seed weight. Standard heterosis for seed yield ranged from -31.9% to 105.5% over the standard checks DCH-32 and GCH-4. Seven hybrids which exhibited >50% standard heterosis can be used for commercial purpose. Two hybrids *viz.*, DPC 10 x RG 297 and DPC 10 x RG 2178 were both heterotic and wilt resistant and are suitable for wilt endemic areas.

Key words: Heterosis, combining ability, gene effects, castor

Introduction

Development of castor hybrids initiated with the introduction of an exotic pistillate line TSP 10 R and its conversion to local germplasm as VP-1, a dwarf S type pistillate line. Use of these pistillate lines facilitated the development of hybrids GCH 3, GAUCH 1, GCH 2, GCH 4 etc., Development of new pistillate sources and male combiners and testing for combining ability is a continuous process of heterosis breeding programme. Several new pistillate lines were developed by conventional breeding *viz.*, LRES 17, DPC 9, DPC 10, DPC 11, DPC 12 , DPC 13, DPC 14, DPC 15, DPC 16 and mutation breeding *viz.*, M 574, M 619, M 571, M 584 (Rao *et al.*, 2003). Regular screening of germplasm in wilt sick plots under AICRP net work identified sources of wilt resistance like RG 47, RG 71, RG 297, RG 2178 and RG 2445 from the germplasm stock. These wilt resistant sources have some undesirable agronomic traits like tall plant height, long duration and perennial nature. An attempt was made in the present study to test the combining ability of wilt resistant sources to develop early/ medium duration high yielding wilt resistant hybrids.

Material and methods

Five pistillate lines *viz.*, DPC-9, DPC-10, M-571, M-584, M-619 and five pollen parents namely RG-47, RG-71, RG-297, RG-2178, RG-2445 with desirable morphological characters and resistance to *Fusarium* were selected. Among the male parents, RG 297 was a registered (IC 296578) resistant source to *Fusarium* (Anonymous, 2003-04). These parents were crossed in line x tester design during *rabi*, 2002. Twenty five hybrids along with two standard checks DCH-32 and GCH-4 were evaluated in a Randomized Block Design (RBD) with two replications at Directorate of Oilseeds Research, Hyderabad during *kharif*, 2003. Each entry was sown in plots of 3.6 x 4.5 m with a spacing of 90 x 45 cm. Standard agronomic management practices were adopted to raise the crop. Observations were recorded on five randomly selected plants for nine characters *viz.*, number of nodes to primary spike, secondary one and two, plant height (cm), total spike length (cm) and effective spike length (cm), effective spikes/plant, number of capsules, hundred seed weight (g) and seed yield/plot was recorded picking wise and cumulated as total seed yield and expressed in kg/ha. Heterosis over checks DCH-32 and GCH-4 was calculated as per standard procedure and combining ability analysis was performed as per Kempthrone (1957). Majority of the male lines used in this study were resistant to *Fusarium* wilt and thus one set of the resulting hybrids were evaluated in the wilt sick plot to identify wilt resistant hybrid.

[1] Student

Results and discussion

Analysis of variance for combining ability revealed the existence of significant differences among the hybrids produced for all the characters. The estimates of variances of general combining ability (GCA) were higher than estimates of variances of specific combining ability (SCA) for the traits studied. Estimates of variances of GCA for secondary raceme two (S_2), hundred seed weight, seed yield indicated the preponderance of additive gene action. Similarly Patel *et al.* (1986), Mehta *et al.* (1991), Pathak and Dangaria (1987), Pathak *et al.* (1989) and Chakrabarty (1997) also reported predominant additive gene action for these characters.

In castor, the development of each node up to primary spike takes 3-4 days as per Shifriss (1961) and it can be used as an indicator of early/late emergence of raceme. In addition, number of nodes to two secondaries (S_1 and S_2) is another good indicator of duration especially under drought or moisture stress. The lower the number of nodes to secondary spikes (<5 of S_1 and S_2), earlier is the maturity of secondary racemes, which is a desirable trait for rainfed conditions. Among the female parents DPC 9 and DPC 10 were good general combiners for earliness at primary as well as at S_1, S_2 stage, short plant height and hundred seed weight. The pistillate line M 584 was a good general combiner for earliness up to primary spike, short plant height and number of effective spikes/plant whereas M 571, M 619 were good general combiners for medium duration of secondaries (Table 1).

Among the male parents RG 47, RG 297 and RG 2445 were good general combiners for early duration as depicted by GCA effects for nodes up to primary and secondaries (S_1 and S_2), short plant height. RG 47 was also a good general combiner for effective spikes/plant where as RG 2178 for hundred seed weight. None of the parental lines were good combiners for total spike length, number of capsules and seed yield (Table 1).

The estimates of SCA variances for all the characters except S_2, 100-seed weight and seed yield revealed the predominant non additive gene action for these traits. Reports by Yadav *et al.* (1978), Swarnalata *et al.* (1984), Fatteh *et al.* (1988), Vindhiya Verman and Ganesan (1995) and Lavanya and Chandramohan (2003) also indicated the predominance of non additive gene action for all these traits.

The *sca* effects for earliness in emergence of primary spike was significant for eight hybrids-DPC 9 x RG 47, DPC 9 x RG 2445, M 571 x RG 47, M 571 x RG 2445. None of the hybrids were desirable specific combiners for early duration to emergence of secondary raceme. Two hybrids *viz.*, DPC 9 x RG 2178, M 619 x RG 47 were desirable specific combiners for total spike length, effective spike length and number of capsules while M 571 x RG 297 for total spike length and effective spike length. These hybrids could be utilized for improving the seed yield through yield component analysis. Three hybrids *viz.*, DPC 10 x RG 47, M 619 x RG 2178 and M 584 x RG 2178 were desirable specific cross combinations for effective spikes per plant, where as DPC 10 x RG 2178 for hundred seed weight. The cross DPC 10 x RG 297 revealed significant sca effects for seed yield (Table 2) and this hybrid recorded low (9%) wilt incidence in wilt sick plot (Anonymous, 2003-04).

Table 1 Estimates of general combining ability (*gca*) effects for different characters in castor

Parents	No. of nodes to			Plant height	Total spike length	Effective spike length	No. of capsules	Effective spikes/ plant	100-seed weight (g)	Seed yield
	Primary	S_1	S_2							
Lines										
DPC 9	-0.956**	-0.788**	-0.716**	-2.982**	-3.214**	-1.760**	-3.160**	-0.124**	1.944*	-48.546
DPC 10	-1.016**	-0.388**	-0.336**	-7.712**	0.196	1.630	-1.320**	0.376	3.854**	89.054
M 571	1.404**	0.292	0.184	5.078	3.346	1.930	0.240	-0.664**	-2.466**	-154.346
M 584	-0.056**	0.332	0.324	-3.402**	-4.054**	-3.670**	-2.860**	1.596*	-3.886**	233.244
M619	0.624**	0.552*	0.544*	9.018	3.726	1.870	7.100	-1.184**	0.554	-119.406
Testers										
RG 47	-0.796**	-0.428**	-0.636**	-4.022**	1.466	1.230	4.500	1.916**	-0.186**	89.264
RG 71	1.404**	0.772**	0.864**	1.958	1.246	3.190	4.760	-0.104**	-1.176**	20.734
RG 297	-0.416**	-0.288**	-0.196**	-1.042**	-1.174**	-1.070**	-1.060**	-1.164**	-0.956**	-88.036
RG 2178	1.524**	0.592*	0.524*	13.198	1.586	1.490	-2.080**	-0.204**	2.754*	101.474
RG 2445	-1.716**	-0.648**	-0.556**	-10.092**	-3.124**	-4.840**	-6.120**	-0.444**	-0.436**	-123.436

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

Table 2 Mean, heterosis and specific combining ability (sca) effects for seed yield and yield components of top five castor hybrids

Character	DPC 9 x RG 47			DPC 10 x RG 297			DPC 10 x RG 2178			M 584 x RG 47		
	Mean	Heterosis	SCA	Mean	Heterosis	SCA	Mean	Heterosis	SCA	Mean	Heterosis	SCA
No. of nodes to Primary	10.8	-6.91	-1.55*	12.6	9.57	-0.06	16.2	40.87**	1.59**	11.1	-3.48	-2.14**
No. of nodes to S_1	3.5	-28.57	-0.51	3.9	-20.41	-0.65	6.9	40.82*	1.47*	4.9	0	-0.23
No. of nodes to S_2	4.6	-13.21	-0.12	5.4	1.89	-0.14	7.0	32.08	0.74	5.4	7.55	-0.06
Plant height (cm)	40.4	4.66	-11.86*	52.1	34.97	1.59	78	102.1**	13.25*	42.4	9.84	-9.44
Total spike length (cm)	31.1	0.32	-3.47	33.1	6.77	-2.24	42.4	36.77*	4.30	28.2	-9.03	-5.53
Effective spike length (cm)	29.0	11.75	-2.82	31.3	20.62	-1.61	41.3	59.15	5.83	23	-11.37	-6.91*
No. of capsules	31	23.02	-3.52	33	30.95	2.2	30.8	22.22	1.02	24	-4.76	-10.82
Effective spikes/ plant	8.9	-35.97*	0.50	6.7	-51.80**	0.88	5.2	-62.59**	-1.58	10.6	45.21	0.48
100-seed weight (g)	33.95	26.92**	1.71	32.15	20.19*	-1.23	41.8	56.26**	4.706**	27	0.93	0.59
Seed yield (kg/ha)	1143	48.6*	150.79	1235	60.61*	283.89*	1406	82.81**	265.13	1426	85.37**	152.85

Character	M 584 x RG 71			M 584 x RG 2445		
	Mean	Heterosis	SCA	Mean	Heterosis	SCA
No. of nodes to Primary	16.7	45.22**	1.26*	15.4	33.91**	3.08**
No. of nodes to S_1	6.2	26.53	-0.13	5.4	10.2	0.49
No. of nodes to S_2	6.9	30.19	-0.36	6.2	16.98	0.36
Plant height (cm)	59	52.85**	1.18	66.7	72.80**	20.93**
Total spike length (cm)	33.8	9.03	0.29	33.7	8.71	4.56
Effective spike length (cm)	33.4	28.71	1.53	29.0	11.75	5.16
No. of capsules	45.8	81.75*	10.72	28.1	11.51	3.9
Effective spikes/ pl	8.0	-42.45**	-0.096	6.7	-51.80**	-1.06
100 seed weight (g)	26.45	-1.12	1.03	27.2	1.68	1.04
Seed yield (kg/ha)	1271	65.18*	66.08	1070	39.08	-9.49

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

The magnitude of standard heterosis in comparison with two checks *viz.*, DCH 32 and GCH 4 ranged from -31.98% to 85.37% and -24.6% to 105.49% respectively. Five hybrids *viz.*, DPC 9 x RG 47, DPC 10 x RG 297, DPC 10 x RG 2178, M 584 x RG 47 and M 584 x RG 71 had shown considerable positive heterosis over DCH 32 and GCH 4 (Table 2). Among them, heterotic hybrids like DPC 9 x RG 47 (48%), DPC 10 x RG 297 (60%) and M 584 x RG 47 (85%) with 11 to 12 nodes to primary spike and 3.5 to 5.4 nodes to S_1 and S_2 were early maturing and suitable for rainfed conditions. The other two hybrids *viz.*, DPC 10 x RG 2178 (82.8%), M 584 x RG 71 (65%) with 16 nodes to primary and 6-7 nodes to S_1 and S_2 were medium maturing and suitable for irrigated conditions. The hybrids DPC 10 x RG 297 (DCH 861) and DPC 10 x RG 2178 (DCH 875) exhibited high standard heterosis and low wilt incidence and thus can be used for commercial purpose as high yielding and wilt resistant hybrids.

Acknowledgement: The authors wish to acknowledge the financial support received from project "Development of hybrid crops - Castor" under NATP (MM) for conducting this experiment and Dr. K. Anjani, Senior Scientist, I/c GMU, DOR, Hyderabad for providing the seed of valuable germplasm lines.

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J. Oilseeds Res., 23(2) : 178-183 (2006)

Combining ability in castor, *Ricinus communis* L.

Y. Chandra Mohan, A. Vishnuvardhan Reddy[1] and T. Nageshwar Rao

Department of Genetics and Plant Breeding, College of Agriculture, Acharya N.G. Ranga Agril. University, Rajendranagar, Hyderabad-500 030, AP

(Received: June, 2005; Revised: September, 2005; Accepted: December, 2005)

Abstract

Combining ability for 10 characters was studied using line x tester mating design involving 4 females and 9 *males in castor. Analyses of combining ability* revealed the existence of significant variation among lines, testers and line x testers for all the characters studied barring oil content in testers. The components of *gca* and *sca* variances indicated the predominance of additive gene action for days to 50 % flowering, days to maturity, number of nodes, plant height, effective spike length, capsules/primary spike and 100-seed weight, while non-additive gene action was predominant for primary spike length, seed yield/plant and oil content. The three lines, DCS-5, DCS-27 and SH-72 and two testers, VP-1 and DPC-9 were identified as good combiners for seed yield per plant. However, the three lines, DCS-5, DCS-9 and DCS-85 and one tester, LRES-17 were found to be best combiners for earliness and associated traits apart from oil content. The per se performance of *crosses is not correlated with the sca effects of* crosses resulted from the parents with either high x high or high x low or low x low *gca* effects for yield and yield component traits.

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

Introduction

Use of hybrids and high yielding varieties developed elsewhere have very low impact in increasing productivity especially under rainfed conditions. Constant efforts to improve yield through hybridization and selection of the parents for heterotic breeding are important in crop improvement programmes. Hence, in any breeding programme the appropriate selection of parents based on their combining ability is a prerequisite. Such studies intended to determine the combining ability, not only provide necessary information regarding the choice of parents but also simultaneously illustrate the nature and magnitude of gene action involved. The line x tester mating design helps in realising the objective to estimate the combining ability of parents and there by selecting superior parents as well as cross combinations. Accordingly, the present investigation was undertaken to have the knowledge of nature of combining ability for yield and other yield attributing characters of some newly developed male and female lines of castor (*Ricinus communis* L.).

Material and methods

Four pistillate lines (females) *viz.*, VP-1, LRES-17, DPC-9 and Geeta were crossed with nine monoecious lines (males) *viz.*, DCS-5, DCS-9, DCS-27, DCS-84, DCS-85, SH-72, 48-1, AVR-1 and Co-1 in a line x tester mating design to obtain 36 hybrids during *rabi*, 2000-2001. The 36 crosses along with their parents were grown in a Randomized Block Design with three replications during *rabi, 2001-2002* at the College of Agriculture, ANGRAU, Rajendranagar. Recommended package of practices was followed with a spacing of 90 x 60 cms. Each plot consisted of two rows with five meter length. Observations were recorded on five randomly selected plants/plot for six characters *viz.*, plant height, number of nodes, primary spike length, effective spike length, capsules/primary spike and seed yield/plant. However, days to 50% flowering, days to maturity, 100-seed weight and oil content were recorded on plot basis. The data were further analysed as per the method suggested by Kempthorne (1957). *Predictability ratios were calculated using the formula given by Griffing (1956):* $\sigma^2 gca/(2\sigma^2 gca+\sigma^2 sca)$.

Results and discussion

The average performance of hybrids was different from that of parents as evident from the significance of parents vs. cross source of variation for all the traits and indicated the presence of heterosis among the hybrids (Table 1). The mean sum of squares attributed to the male and female parents of the hybrids which provide a measure of their general combining ability and the interaction between male and female parents as a measure of specific combining ability (Rojas, 1951) were significant for all the traits barring oil content in testers, indicating the role of both additive and non-additive gene effects for the traits. The estimates of components of variance and the

[1] Senior Scientist (Plant Breeding), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, A.P.

predictability ratios indicated the predominance of additive gene action for days to 50 % flowering, days to maturity, number of nodes, plant height, effective spike length, number of capsules per primary spike and 100-seed weight. It implied that improvement in these traits is possible through selection in segregating generations. These results are akin to the reports of Dangaria *et al.* (1987), Mehta *et al.* (1991) and Mehta (2000). However, for primary spike length, seed yield/plant and oil content the magnitude of *sca* variance were higher than *gca* variance indicating the predominance of non-additive gene action suggesting the possibility of improvement through hybridization in the traits. These results are in conformity with the reports of Vindhiyavarman and Ganesan (1995), Chakrabarty (1997), Kavani *et al.* (2001), Tank *et al.* (2003) and Solanki *et al.* (2004).

The results of *gca* effects (Table 2) revealed that the lines, SH-72 and DCS-27 and the testers, VP-1 were found to be good combiners, while the lines, DCS-85, Co-1 and DCS-84 and the tester, LRES-17 were found to be poor combiners for seed yield/plant, number of capsules/primary spike, effective spike length and primary spike length. Manivel and Hussain (1997) reported VP-1 as a good general combiner for seed yield and primary spike length. For capsules/primary spike, the tester, DPC-9 recorded the highest significant positive *gca* effect. The lines, Co-1 and AVR-1 and the tester, DPC-9 contributed maximum desirable alleles for 100-seed weight as evidenced from high significant *gca* effects and high *per se* performance. For oil content, DCS-85, DCS-9, DCS-5, AVR-1 and the tester, LRES-17 were identified as good general combiners. Since, earliness and dwarf nature is desirable, parents with negative *gca* effects for days to 50% flowering, days to maturity, number of nodes, plant height were considered as best combiners. Thus lines, DCS-9, DCS-5, DCS-85 and DCS-84 and the tester, LRES-17 were found to be good general combiners. Similarly, Manivel *et al.* (1998) identified LRES-17 as a good general combiner for earliness.

Table 1 Analysis of variance for combining ability for yield and yield component characters in castor

Source	d.f.	Days to 50% flowering	Days to maturity	No. of nodes	Plant height (cm)	Primary spike length (cm)	Effective spike length (cm)	Capsules/ primary spike	100-seed weight(g)	Seed yield/ plant (g)	Oil content (%)
Replication	2	10.13	0.50	0.25	8.16	49.14*	85.23**	6.84	2.18	104.00	0.44
Treatment	48	298.42**	280.12**	15.41**	654.59**	338.74**	237.95**	305.64**	202.93**	9520.83**	18.76**
Parents	12	453.47**	455.82**	25.26**	1511.20**	628.57**	480.10**	474.85**	583.88**	5066.20**	19.07**
Crosses	35	170.83**	154.06**	10.79**	342.33**	245.79**	155.43**	239.37**	78.18**	7908.63**	19.06**
Parents vs. Crosses	1	2903.38**	2583.75**	58.77**	1304.19**	114.02**	220.49**	594.90**	9.81**	119403.6**3	4.57*
Lines	8	557.36**	403.34**	27.10**	625.74**	391.01**	264.84**	605.82**	254.27**	17902.25**	33.38*
Testers	3	218.71**	468.71**	27.21**	1515.09**	886.89**	580.17**	540.99**	143.15**	14850.33**	31.84
Lines x Testers	24	36.00**	31.63**	3.31**	101.26**	117.25**	65.87**	79.51**	11.36**	3709.71**	12.69**
Error	96	8.82	7.89	0.47	15.73	15.67	11.95	21.84	1.18	121.80	0.38
s^2gca		18.05	20.74	1.22	49.70	26.75	19.98	25.33	9.61	649.57	1.02
s^2sca		9.07	7.91	0.95	28.51	33.88	10.65	19.21	3.38	1195.96	4.11
s^2gca/s^2sca		1.99	2.62	1.28	1.74	0.79	1.88	1.32	2.84	0.54	0.25
Degree of dominance		0.50	0.44	0.62	0.53	0.80	0.52	0.62	0.42	0.96	1.42
Predictability ratio		0.80	0.84	0.72	0.78	0.61	0.79	0.73	0.85	0.52	0.33

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

It was observed that *per se* performance of parents for majority of the traits in general, was related to their *gca* effects. Thus, if a trait is unidirectionally controlled by a set of alleles and additive effects are important, the choice of parents based on *per se* performance may be effective. These results are akin to the earlier reports (Sudhakar *et al.*, 1995, Mehta, 2000; Joshi *et al.*, 2002). Further, parents which exhibited significant *gca* effects for seed yield per plant also possessed high significant *gca* effects for some of the yield components.

The study of *sca* effects (Table 3) revealed that significant and desirable effects were observed in 5 hybrids each for days to 50 % flowering, days to maturity, effective spike length and capsules per primary spike, 6 hybrids for plant height, 7 hybrids for 100-seed weight, eight hybrids each for number of nodes, primary spike length, 13 hybrids for seed yield/plant and 14 for oil content. Majority of the crosses with significant *sca* effects involved the parents having one good and one poor combiner parents for all the characters indicating the significance of non-additive gene action in governing the traits. It is in conformity with the results of Singh and Srivastava (1982) who observed that most of the superior combinations showed at least one good general combiner and suggested that combining ability of a parent might be considered as a reliable guide in the prediction of yield potential of a cross.

For seed yield/plant, out of 13 crosses having significant positive *sca* effects, 7 crosses (54%) had parents with high x low *gca* effects, while 3 crosses (23%) each had parents with high x high and low x low gca effects. In the present study it was observed that majority of the higher *sca* effects involved both or at least one good combiner indicating additive x additive or additive x dominance type of gene action.

A comparison of hybrids and their *sca* effects (Table 4) revealed that high *per se* performance of crosses was not always related with their higher *sca* effects in majority of the traits. Therefore, *per se* performance should be given preference over *sca* effects while choosing best cross combinations, since *sca* effects are merely a measure of deviation of F_1 performance from prediction based on parental *gca* effects. These results are akin to the reports of Manivel *et al.* (1998) and Mehta (2000). For oil content, all the crosses except one exhibited significant positive *sca* effects. The parents involved in these crosses were either high x high or high x low general combiners indicating the importance of both additive and non-additive gene action.

Table 2 General combining ability effects of parents for ten characters in castor

Parents	Days to 50% flowering	Days to maturity	No. of nodes	Plant height (cm)	Primary spike length (cm)	Effective spike length (cm)	Capsules/ primary spike	100-seed weight (g)	Seed yield/ plant (g)	Oil content (%)
Lines										
DCS-5	-5.47**	-5.64**	-1.33**	-8.90**	-2.27*	-0.09	-1.20	-1.99**	7.42*	1.43**
DCS-9	-5.89**	-5.31**	-1.32**	-5.55**	-2.74*	-0.25	-3.86**	0.53	-0.09	1.64**
DCS-27	-0.97	0.61	0.20	2.60*	2.71*	4.91**	12.61**	-7.66**	39.97**	-2.95**
DCS-84	-4.81**	-3.14**	-0.88**	-2.38*	-0.51	0.96	-4.31**	-1.19**	-6.64*	-1.49**
DCS-85	-5.06**	-3.47**	-1.52**	-8.76**	-6.17**	-4.27**	-5.66**	-1.85**	-33.74**	2.15**
SH-72	4.53**	2.69**	1.32**	13.20**	12.78**	9.03**	10.21**	-0.27	63.95**	-0.65**
48-1	0.03	-0.06	0.28	5.35**	0.38	-1.02	-1.54	-1.07**	2.09	0.11
AVR-1	2.44**	0.94	0.15	0.59	1.79	-2.69**	-8.21**	4.61**	-2.25	0.73**
Co-1	15.19**	13.36**	3.10**	3.84**	-5.97**	-6.59**	1.96	8.90**	-70.72**	-0.99**
SE ±	0.86	0.81	0.20	1.14	1.14	1.00	1.35	0.31	3.19	0.18
CD (0.05)	1.68	1.59	0.39	2.24	2.24	1.96	2.64	0.61	6.24	0.35
CD (0.01)	2.21	2.09	0.51	2.95	2.94	2.57	3.48	0.81	-8.21	0.46
Testers										
VP-1	0.27	-0.04	0.71**	2.15**	8.52**	6.49**	2.83**	-1.15**	28.56**	-1.48**
DPC-9	-0.47	0.81	-0.67**	-2.55**	-2.86**	-1.70*	4.37**	3.31**	9.49**	0.19
LRES-17	-3.36**	-5.44**	-1.04**	-8.66**	-3.74**	-4.39**	-5.48**	-1.88**	-22.24**	1.13**
GEETA	3.56**	4.67**	0.99**	9.06**	-1.92*	-0.40	-1.72	-0.29	-15.81**	0.16
SE ±	0.57	0.54	0.13	0.76	0.76	0.67	0.90	0.21	2.12	0.12
CD (P=0.05)	1.12	1.06	0.26	1.50	1.49	1.30	1.76	0.41	4.16	0.23
CD (P=0.01)	1.47	1.39	0.34	1.97	1.96	1.71	2.32	0.54	5.47	0.31

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

Table 3 Specific combining ability effects of parents for 10 characters in 36 crosses of castor

Cross	Days to 50% flowering	Days to maturity	No. of nodes	Plant height (cm)	Primary spike length (cm)	Effective spike length (cm)	Capsules/ primary spike	100-seed weight (g)	Seed yield/ plant (g)	Oil content (%)
VP-1 x DCS-5	0.06	1.12	-0.46	3.53	-0.62	2.58	8.05**	1.30*	38.62**	1.58**
VP-1 x DCS-9	-1.19	-2.55	-1.10**	0.85	-6.56**	-3.46	-2.96	0.43	3.46	1.67**
VP-1 x DCS-27	-2.10	-0.46	-0.88*	5.54*	6.46**	7.84**	7.70**	1.24*	4.71	0.11
VP-1 x DCS-84	0.40	-1.05	-0.81*	-3.32	-4.79*	-2.34	-4.20	-1.24*	4.38	-1.13**
VP-1 x DCS-85	-1.69	-0.05	-1.10**	-1.00	-1.72	-0.77	-4.03	2.73**	19.30**	-2.88**
VP-1 x SH-72	1.73	-0.88	1.23**	4.03	4.06	-1.27	-5.43*	0.77	-35.31**	-0.11
VP-1 x 48-1	0.56	1.87	1.70**	-5.25*	-0.27	1.11	2.72	0.35	13.89*	-2.53**
VP-1 x AVR-1	-0.19	3.20*	0.46	-5.55*	7.58**	1.84	-2.20	-2.04**	-5.76	1.63**
VP-1 x CO-1	2.40	-1.21	0.95*	1.20	-4.12	-5.52**	0.35	-3.53**	-43.28**	1.66**
DPC-9 x DCS-5	-0.86	-3.06	-0.44	-2.83	-1.37	-1.63	-10.16**	0.87	-17.47**	0.50
DPC-9 x DCS-9	-0.11	0.27	0.28	3.49	5.29*	2.87	5.69*	0.39	47.53**	-3.45**
DPC-9 x DCS-27	1.97	1.35	1.17**	6.88**	4.38	2.90	5.56*	0.31	23.49**	2.10**
DPC-9 x DCS-84	2.14	4.77**	0.64	4.32	7.39**	4.99	4.22	1.78**	7.35	3.60**
DPC-9 x DCS-85	4.39*	4.44**	0.82*	-0.16	1.79	-0.05	1.49	-2.27**	-5.03	1.70**
DPC-9 x SH-72	*-2.86*	*0.27*	*-1.49***	*-1.66*	*-12.49***	*-8.61***	*-2.11*	*-1.36**	-21.94**	-0.83*
DPC-9 x 48-1	-0.03	-0.31	-1.58**	1.99	0.04	-0.96	-1.96	-3.22**	-63.99**	1.10**
DPC-9 x AVR-1	-1.78	-1.98	0.34	-7.38**	-5.51*	-1.23	0.25	-0.83	-5.60	-3.22**
DPC-9 x Co-1	-2.86	-5.73**	0.27	-4.63*	0.46	1.74	-2.99	4.33**	35.66**	-1.48**
LRES-17 x DCS-5	5.03**	5.86**	1.53**	5.41*	4.71*	2.32	-1.18	0.14	8.24	-2.44**
LRES-17 x DCS-9	2.11	0.53	-0.34	0.06	-5.49*	-4.44*	-2.32	-0.71	-42.71**	0.71*
LRES-17 x DCS-27	0.86	-1.39	0.34	-2.28	-0.67	-1.14	-4.45	-1.24*	13.62*	-0.51
LRES-17 x DCS-84	2.36	-0.31	0.52	1.10	-5.72*	-3.79	2.74	-0.65	-26.85**	-0.75*
LRES-17 x DCS-85	1.94	-0.64	0.52	5.08	-3.92	-1.96	0.68	-1.10	-33.26**	-0.93**
LRES-17 x SH-72	-4.64**	-0.81	-0.45	-4.02	0.59	2.81	1.75	0.13	38.14**	0.38
LRES-17 x 48-1	-1.47	-1.06	-0.34	-2.77	6.26**	3.92*	3.83	2.13**	-0.91	1.94**
LRES-17 x AVR-1	-3.56*	-3.72*	-1.35**	1.00	1.51	-0.28	-1.03	1.99**	47.67**	0.61
LRES-17 x Co-1	-2.64	1.53	-0.43	-3.59	2.74	2.56	0.00	-0.69	-3.94	0.99**
Geeta x DCS-5	-4.23	-3.92*	-0.63	-6.11**	-2.71	-3.27	3.30	-2.31**	-29.39**	0.36
Geeta x DCS-9	-0.81	1.75	1.16**	-4.40	6.75**	5.03*	-0.41	-0.11	-8.27	1.08**
Geeta x DCS-27	-0.73	0.50	-0.63	-10.14**	-10.16**	-9.60**	-8.81**	-0.31	-41.82**	1.70**
Geeta x DCS-84	-4.90**	-3.42*	-0.35	-2.10	3.12	1.15	-2.75	0.12	15.12*	1.72**
Geeta x DCS-85	-4.65**	-3.75*	-0.24	-3.91	3.85	2.78	1.86	0.64	18.99**	2.12**
Geeta x SH-72	5.77**	1.42	0.72	1.65	7.84**	7.08**	5.79*	0.46	19.12**	0.56
Geeta x 48-1	0.94	-0.50	0.22	6.04**	-6.03**	-4.07*	-4.59	0.74	51.01**	-0.52
Geeta x AVR-1	5.52**	2.50	0.55	11.94**	-3.58	-0.34	2.98	0.88	-36.32**	0.98**
Geeta x Co-1	3.10	5.42**	-0.79*	7.02**	0.92	1.23	2.64	-0.11	11.56	-1.17**
SE ±	1.71	1.62	0.39	2.29	2.29	2.00	2.70	0.63	6.37	0.36
CD (0.05)	3.36	3.18	0.77	4.49	4.48	3.91	5.29	1.23	12.49	0.70
CD (0.01)	4.42	4.18	1.02	5.90	5.89	5.14	6.95	1.61	16.41	0.92

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

Table 4 Performance of five superior crosses for each of the ten characters in castor

Cross	*Per se* performance	sca effect	P_1 *Per se* performance	P_1 *gca* effect	P_2 *Per se* performance	P_2 *gca* effect
Days to 50% flowering						
LRES-17 x DCS-9	44.00	2.11	54.00	-3.36 **	45.33	-5.89 **
VP-1 x DCS-9	44.33	-1.19	65.33	0.27	45.33	-5.89 **
DPC-9 x DCS-5	44.33	-0.86	61.33	-0.47	51.00	-5.47 **
VP-1 x DCS-85	44.67	-1.69	65.33	0.27	51.00	-5.06 **
DPC-9 x DCS-9	44.67	0.11	61.33	-0.47	45.33	-5.89
Days to maturity						
LRES-17 x DCS-5	100.33	5.86 **	114.33	-5.44 **	106.33	-5.64 **
LRES-17 x DCS-85	101.00	-0.64	114.33	-5.44 **	109.00	-3.47 **
LRES-17 x DCS-84	101.67	-0.31	114.33	-5.44 **	115.67	-3.14 **
VP-1 x DCS-9	102.67	-2.55	127.33	-0.04	101.00	-5.31 **
DPC-9 x DCS-5	102.67	-3.06	124.33	0.81	106.33	-5.64 **
Number of nodes						
LRES-17 x DCS-9	9.20	-0.34	11.53	-1.04 **	8.80	-1.32 **
DPC-9 x DCS-5	9.47	-0.44	12.93	-0.67 **	10.73	-1.33 **
LRES-17 x AVR-1	9.67	-1.35 **	11.53	-1.04 **	14.30	0.15
LRES-17 x DCS-85	9.87	0.52	11.53	-1.04 **	11.33	-1.52 **
DPC-9 x 48-1	9.93	-1.58 **	12.93	-0.67 **	14.87	0.28
Plant height (cm)						
DPC-9 x DCS-5	33.07	-2.83	67.00	-2.55 **	33.93	-8.90 **
LRES-17 x DCS-9	33.20	0.06	23.93	-8.66 **	36.47	-5.55 **
LRES-17 x DCS-85	35.00	5.08 **	23.93	-8.66 **	39.93	-8.76 **
LRES-17 x DCS-5	36.20	5.41 **	23.93	-8.66 **	33.93	-8.90 **
DPC-9 x DCS-85	35.87	-0.61	67.00	-2.55 **	39.93	-8.76 **
Primary spike length (cm)						
VP-1 x SH-72	71.20	4.06	61.47	8.52 **	59.13	12.78 **
Geeta x SH-72	64.53	7.84 **	53.87	-1.92 **	59.13	12.78 **
VP-1 x AVR-1	63.73	7.58 **	61.47	8.52 **	57.07	1.79
VP-1 x DCS-27	63.53	6.46 **	61.47	8.52 **	30.33	2.71
LRES-17 x SH-72	55.47	0.59	54.33	-3.74 **	59.13	12.78 **
Effective spike length (cm)						
VP-1 x DCS-27	60.33	7.84 **	54.73	6.49 **	28.33	4.91 **
Geeta x SH-72	56.80	7.08 **	51.73	-0.40	48.73	9.03 **
VP-1 x SH-72	55.33	-1.27	54.73	6.49 **	49.73	9.03 **
VP-1 x DCS-5	50.07	2.58	54.73	6.49 **	24.33	-0.09
LRES-17 x SH-72	48.53	2.81	48.27	-4.39 **	49.73	9.03 **
No. of capsules/primary spike						
VP-1 x DCS-27	70.20	7.70 **	49.53	2.83 **	41.00	12.61 **
DPC-9 x DCS-27	69.60	5.56 *	54.53	4.37 **	41.00	12.61 **
Geeta x SH-72	61.33	5.79 *	57.53	-1.72	65.33	10.21 **
DPC-9 x SH-72	59.53	-2.11	54.53	4.37 **	65.33	10.21 **
VP-1 x DCS-5	56.73	8.05 **	49.53	2.83 **	30.13	-1.20
100 seed weight (g)						
DPC-9 x Co-1	50.22	4.33 **	31.71	3.31 **	74.42	8.90 **
Geeta x Co-1	42.17	-0.11	29.40	-0.29	74.42	8.90 **
DPC-9 x AVR-1	40.77	-0.83	31.71	3.31 **	46.82	4.61 **
LRES-17 x Co-1	40.01	-0.69	28.34	-1.88 **	74.42	8.90 **
Geeta x AVR-1	38.89	0.89	29.40	-0.29	46.82	4.61 **
Seed yield/plant (g)						
LRES-17 x SH-72	360.46	38.14 **	192.26	-22.24 **	248.06	63.95 **
VP-1 x DCS-5	355.20	38.62 **	205.65	28.56 **	200.53	7.42 *
VP-1 x DCS-27	353.84	4.71	205.65	28.56 **	157.66	39.97 **
DPC-9 x DCS-27	353.56	23.49 **	276.05	9.49 **	157.66	39.97 **
Geeta x SH-72	347.86	19.12 **	292.76	-15.81 **	248.06	63.95 **
Oil content (%)						
Geeta x DCS-85	53.04	2.12 **	48.87	0.16	49.45	2.15 **
DPC-9 x DCS-85	52.64	1.70 **	52.27	0.19	49.45	2.15 **
LRES-17 x DCS-9	52.08	0.71 *	50.84	1.13 **	46.77	1.64 **
LRES-17 x 48-1	51.79	1.94 **	50.84	1.13 **	48.07	0.11
Geeta x DCS-9	51.49	1.08 **	48.87	0.16	46.77	1.64 **

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

Since, the degree of dominance for seed yield and oil content were near to unity and superior crosses involved the parents with good *gca* effects, it is recommended that the crosses having desirable *sca* effects could be handled through recurrent or reciprocal recurrent selection for the improvement of yield and oil content. Further, the crosses with high *per se* performance and substantial heterosis over better check could be exploited through heterosis breeding.

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J. Oilseeds Res., **23**(2) : 184-186 (2006)

Inheritance of bloom nature in castor, *Ricinus communis* L.

Y. Chandra Mohan, A. Vishnuvardhan Reddy[1] and T. Nageshwar Rao

Dept. of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad-500 030, AP

(Received: June, 2005; Revised: August, 2005; Accepted: October, 2005)

Abstract

Six crosses *viz.*, VP-1 x DCS-9, VP-1 x 48-1, VP-1 x Co-1, LRES-17 x Co-1, DPC-9 x SH-72, DCS-9 x 48-1 involving parents with triple, double and zero bloom were observed to know the mode of inheritance of bloom nature in castor. The results revealed that bloom nature is governed by single gene involving multiple alleles. Allele for triple bloom is completely dominant over allele for double bloom and partially dominant over allele for zero bloom. Further, allele for double bloom is also partially dominant to allele for zero bloom.

Key words: Castor, *Ricinus communis* L., bloom, inheritance

Introduction

Castor (*Ricinus communis* L.) plant is often characterized by the presence of waxy coating, called bloom. Based on distribution of bloom on different plant parts various classes (triple, double, single, zero) have been reported by Harland (1920), Peat (1928), Patwardhan (1931) and Narain (1952). Bloom is considered as desirable character since the triple bloom varieties are more resistant to jassids (Natarajan *et al.*, 1986) and tolerant to drought. Further, it can also be used as efficient diagnostic marker in identifying varieties, hybrids and their parents. Hence, it is worthwhile to study the genetics of bloom nature. However, most of the available literature provides information on the inheritance of bloom by taking only two classes as presence or absence of bloom. To know complete inheritance, observations on the basis of triple, double, single and zero bloom are essentially required (Solanki and Joshi, 2001). Keeping this in view, present study was aimed at studying mode of inheritance of different classes of bloom in castor.

Material and methods

The material consisted of seven parents viz., VP-1 (triple), LRES-17 (triple), DPC-9 (zero), DCS-9 (double), 48-1 (double), SH-72 (double) and CO-1 (zero) with different classes of bloom. In *rabi*, 2000-01, six crosses between parental lines possessing different bloom classes, two crosses each of the three combinations *viz.*, triple vs. double, triple vs. zero and zero vs. double were made. F_1 hybrids were selfed and backcrossed to both the parents to obtain B_1 and B_2 generations during *kharif*, 2001. In *rabi*, 2001-02, all the six populations (P_1, P_2, F_1, F_2, B_1 and B_2) were evaluated for segregation of bloom frequencies to test the goodness of fit to expected ratios. In each cross, a population of 15 plants in parents and hybrids, 200 to 300 plants in F_2 and 100 to 200 plants each in B_1 and B_2 generations were studied to record the segregation pattern for each character. Recommended package of practices was followed with a spacing of 90 x 60 cms. The study was carried out at the College of Agriculture, ANGRAU, Rajendranagar, Hyderabad.

Results and discussion

The crosses between triple vs. double bloom parents (VP-1 x DCS-9 and VP-1 x 48-1) gave the F_1 plants with triple bloom. The F_2 population of both the crosses segregated in a ratio of 3 triple: 1 double bloom (Table 1). The backcross progenies involving triple bloom parent (VP-1) as recurrent parent showed all the plants with triple bloom, whereas the backcross of F_1 plants with respective double bloom parent gave the segregation with the good fit to 1 triple: 1 double bloom ratio. It indicated that the triple bloom is dominant over double bloom and is controlled by single gene. Patwardhan (1931) also reported dominance of triple bloom over double bloom.

In two crosses *viz.*, VP-1 x Co-1 and LRES-17 x Co-1 involving triple bloom vs. zero bloom, the F_1 plants appeared similar to double bloom, but had slight bloom on dorsal surface of the leaf, it was classified as partial triple bloom. The F_2 plants of both the crosses segregated at the expected ratio of 1:2:1 of triple, partial triple and zero bloom, respectively (Table 2). The backcross progenies involving zero bloom parent (CO-1) as recurrent parent gave the plants with a segregation of 1 partial triple: 1 zero, whereas the back cross progeny involving respective double bloom parent as recurrent parent segregated with the expected ratio of 1 triple : 1 partial triple. These results clearly showed that triple bloom is partially dominant over zero bloom and is under single gene control. Narain (1961) reported partial dominance of triple bloom over single bloom.

[1] Senior Scientist (Plant Breeding), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, A.P.

Table 1 Expression of bloom nature (triple vs. double) in F_1, F_2 and backcross generations in two different crosses of castor

Cross	F_1 phenotype	Generation	Segregation			Expected ratio	χ^2 value	P-range
			Triple	Double	Total			
Triple x Double								
VP-1 x DCS-9	Triple	F_2	206	82	288	3:1	1.85	0.20-0.10
		B_1 (F_1 x VP-1)	172	-	172	-	-	-
		B_2 (F_1 x DCS-9)	74	78	152	1:1	0.11	0.75-0.50
VP-1 x 48-1	Triple	F_2	198	70	268	3:1	0.17	0.75-0.50
		B_1 (F_1 x VP-1)	199	-	199	-	-	-
		B_2 (F_1 x 48-1)	75	84	159	1:1	0.51	0.50-0.25

Table 2 Expression of bloom nature (triple vs. zero) in F_1, F_2 and backcross generations in two different crosses of castor

Cross	F_1 phenotype	Generation	Segregation				Expected ratio	χ^2 value	P-range
			Triple	Partial Triple	Zero	Total			
Triple x Zero									
VP-1 x CO-1	Partial triple	F_2	68	126	62	256	1:2:1	0.34	0.90-0.75
		B_1 (F_1 x VP-1)	91	96	-	187	1:1	0.13	0.75-0.50
		B_2 (F_1 x CO-1)	-	54	59	113	1:1	0.22	0.75-0.50
LRES-17 x CO-1	Partial triple	F_2	62	124	59	245	1:2:1	0.11	0.95-0.90
		B_1 (F_1 x LRES-17)	84	65	-	149	1:1	2.42	0.25-0.10
		B_2 (F_1 x CO-1)	-	64	49	113	1:1	1.99	0.25-0.10

Table 3 Expression of bloom nature (zero vs. double) in F_1, F_2 and backcross generations in two different crosses of castor

Cross	F_1 phenotype	Generation	Segregation				Expected ratio	χ^2 value	P-range
			Double	Partial double	Zero	Total			
Zero x Double									
DPC-9 x SH-72	Partial triple	F_2	76	151	59	286	1:2:1	4.79	0.10-0.05
		B_1 (F_1 x DPC-9)	-	61	49	110	1:1	1.31	0.50-0.25
		B_2 (F_1 x SH-72)	106	98	-	204	1:1	0.31	0.75-0.50
DPC-9 x 48-1	Partial triple	F_2	64	138	66	268	1:2:1	0.27	0.90-0.75
		B_1 (F_1 x DPC-9)	-	61	63	124	1:1	0.03	0.90-0.75
		B_2 (F_1 x 48-1)	57	59	-	116	1:1	0.03	0.90-0.75

Further, in the crosses involving zero bloom vs. double bloom parents (DPC-9 x SH-72 and DPC-9 x 48-1), the F_1 hybrids were similar to single bloom but slight bloom was also observed on lower surface of leaf near to veins and were grouped as partial double bloom, it indicated that double bloom is partially dominant over zero bloom. The F_2 population of both the crosses gave a segregation of 1 double : 2 partial double : 1 zero bloom ratio (Table 3) inferring that the trait is governed by single gene. These results are further confirmed with the back cross segregation ratios. However, Peat (1928) observed the F_2 ratio of 9:3:4 (recessive epistasis) of double, single and

zero bloom, respectively from the cross involving parents with double and zero bloom, whereas Zimmerman (1957) and Solanki and Joshi (2001) reported that bloom nature is monogenically dominant over zero bloom.

Based on the inheritance pattern observed in six crosses involving triple, double and zero bloom parents, it could be concluded that the bloom nature in castor is controlled by single gene involving multiple alleles. Allele for triple bloom is completely dominant to allele for double bloom and partially dominant over allele for zero bloom, whereas allele for double bloom is partially dominant over allele for zero bloom. Harland (1920; 1928) reported either complete or partial dominance of bloom in F_1.

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J. Oilseeds Res., 23(2) : 187-190 (2006)

Heterosis and inbreeding depression in linseed, *Linum usitatissimum* L.

S.S. Rao

Department of Plant Breeding and Genetics, Indira Gandhi Krishi Vishwa Vidyalaya, Raipur-492 006, MP

(Received: June, 2005; Revised: November, 2005; Accepted: January, 2006)

Abstract

Heterosis and inbreeding depression in 12 crosses derived from seven diverse parents and genetic variability studies in linseed was carried out during *rabi*, 2002-03. The experimental material comprised 24 populations and seven parents for 11 different characters revealed considerable amount of variability for all the characters. Most of the characters were less influenced by environment as minor differences recorded between genotypic and phenotypic coefficients of variation. High heritability with high genetic advance was observed for number of capsules per plant, number of seeds/plant and seed yield/plant, might be due to additive gene effects. Heterosis and inbreeding depression was observed positive in direction in most of the characters. Maximum heterosis was recorded for seed weight/plant followed by number of capsules/plant and number of seeds/plant.

Key words: Linseed, heterosis, inbreeding depression

Introduction

Linseed (*Linum usitatissimum* L.) is an important *rabi* oilseed crop of Chhattisgarh. In Chhattisgarh linseed is grown mostly under rainfed as relay cropping "*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 presence of nature and extent of genetic variability. The selective advantage of any population depends upon an amount of heritable variability present in the population. Heritability estimates are useful in understanding the pattern of inheritance of quantitative traits and genetic advance is also a useful measure to predict gain in specified selection intensity.

In the present study another objective was to assess the extent of heterosis present in F_1 hybrids and to know the possibility of exploiting heterosis in hybrid breeding programme (Dubey and Singh, 1968). Another aim was to find out whether there is a relationship between high heterosis in F_1 and superior segregants in F_2. The extent of heterosis of and inbreeding depression can also give an idea about the genetic control of a particular character.

Material and methods

Seven divergent parents *viz.*, Kiran, R-552, LCK-88062, T-397, Polf-14, Polf-22 and SIKO-10 and 12 F_1 and 12 F_2 populations were grown in Randomized Complete Block Design with three replications at oilseed experimental area in Research Farm of IGAU, Raipur during *rabi*, 2002-03. These crosses were selected from the crosses developed in earlier years by adopting the mating system of diallel/line x tester. The parents and F_1s were grown in single rows, whereas F_2 populations were grown in 6 rows, the row length being 4 m. A row-to-row distance of 30 cm and plant-to-plant distance of 5 cm was maintained. Five competitive plants were randomly tagged in the parents and F_1s and twenty plants were tagged in the F_2s of all the twelve crosses to record observations on yield traits (Table 1). Genetic parameters of variation, heterosis over better parent and inbreeding depression for all the characters were estimated (Johnson *et al.*, 1955; Grafius, 1959; Allard, 1960).

Results and discussion

High genotypic coefficient of variation were observed for number of capsules/plant, seed yield/plant, number of seeds/plant and number of secondary branches/plant which indicative of the presence of considerable amount of genetic variability in the experimental material (Table 1).

Heritability estimates were high for all the characters except number of primary and secondary branches/plant and number of seeds/capsule. High heritability coupled with high genetic advance along with genotypic as well as phenotypic coefficients of variation observed for number of capsules/plant, number of seeds/plant and seed yield/plant might be due to additive gene effects indicate a good scope for improvement of these traits while selecting the populations. The results of the study are in agreement with the findings of earlier workers Dixit and Dubey (1985) and Mirza *et al.* (1996).

Heterosis over better parent and inbreeding depression expressed in percentage over mean estimated for each character and presented in Table 2. All the crosses except T-397 x SIKO-10 and LCK-88062 x T-397 showed positive heterosis for days to flower ranging from -5.42 to 29.50. Majority of the crosses showed positive inbreeding depression. However, two crosses, LCK-88062 x T-397 and Polf-14 x Polf-22 showed negative inbreeding depression as majority of the segregants of these crosses flower earlier than their hybrids. All the crosses expressed positive heterosis for days to maturity except three crosses i.e., R-552 x LCK-88062, Polf-14 x SIKO-10 and Polf-22 x SIKO-10 showed negative heterosis. It is also true in case of inbreeding depression as majority of the segregates of these crosses mature earlier than their hybrids.

All the crosses showed positive heterosis and inbreeding depression for plant height. This population will provide much scope for selection for dwarf types. Majority of the crosses heterosis and inbreeding for primary and secondary branches/plant were in positive direction. All the crosses showed significant heterosis for capsules/ plant and significant negative heterosis for number of seeds/capsule also coupled with negative inbreeding depression. Except Kiran x LCK-88062 and Polf-14 x Polf-22, all the crosses showed positive heterosis coupled with positive inbreeding depression for 1000-seed weight. Number of seeds/plant showed positive heterosis coupled with positive inbreeding depression. The value of heterosis for harvest index ranged from -26.90 to 43.42 and inbreeding depression ranged from -36.80 to 20.37. The value of heterosis for seed yield are positive and significant which ranged from 61.94 to 264.11 coupled with positive inbreeding depression. Heterosis for seed yield in linseed was reflected through heterosis in primary and secondary branches/plant and capsules and number of seeds/plant confirms the earlier findings of Rao and Singh (1983), Verma and Mahto (1996), Rao *et al.* (2001) and Bhateria *et al.* (2001).

These studies could help the breeder to concentrate on only a few promising crosses rather than handling many, since superior crosses showing heterosis were also through superior segregants. The improvement of linseed yields would be possible by adopting scheme of inter-mating in the F_2 and resulting generation may be advantageous.

Table 1 Genetic parameters of variation for yield and yield attributes in linseed

Character	Mean	SEm±	Range		GCV (%)	PCV (%)	h^2 (bs)	GA (% over mean)
			Minimum	Maximum				
Days to flower	57.4	1.32	51.3	69.7	9.56	10.39	85.2	30.0
Days to maturity	109.4	1.33	101.3	117.3	4.27	4.76	80.4	12.7
Plant height(cm)	65.7	2.50	54.57	82.13	11.46	13.22	75.1	32.4
Number of primary branches/ plant	4.2	0.57	2.73	6.13	15.07	28.14	28.6	20.8
Number of secondary branches/ plant	15.8	2.89	8.40	30.4	29.79	43.54	46.8	58.4
Number of capsules/ plant	55.7	6.17	16.1	116.8	41.98	46.16	82.7	128.1
Number of seeds/ capsule	6.7	0.58	5.53	8.33	8.38	17.35	23.3	10.1
1000-seed weight (g)	5.8	0.24	4.64	7.46	12.36	14.34	74.4	34.7
Number of seeds/plant	327.6	33.5	122.2	556.0	32.38	36.90	77.0	93.3
Harvest index (%)	24.6	1.36	14.13	36.65	19.66	22.57	82.1	62.1
Seed yield/ plant (g)	1.93	0.25	0.583	3.41	39.62	45.54	75.7	112.6

GCV = Genotypic coefficient of variation; PCV = Phenotypic coefficient of variation; h2(bs) = Heritability in broad sense; GA = Genetic advance

Table 2 Heterosis over better parent and breeding depression in 12 crosses in linseed for yield and its components

Name of the cross	Days to flower		Days to maturity		Plant height (cm)		No. of primary branches/plant	
	Het(BP)	ID%	Het(BP)	ID%	Het(BP)	ID%	Het(BP)	ID%
Kiran x R-552	18.65**	16.86	5.27**	1.29	17.03**	4.93	11.33	14.25
Kiran x LCK-88062	4.28	0.00	0.00	0.00	29.20**	14.65	7.86	24.28
Kiran x T-397	14.90**	16.21	4.18**	4.01	17.52**	9.91	24.17	30.80
R-552 x LCK-88062	6.35*	0.54	-2.61	-2.68	25.29**	12.90	4.76	-4.54
R-552 x T-397	10.19**	10.47	1.47	1.45	9.12	13.93	9.17	16.79
LCK-88062 x T-397	-5.42	-5.74	0.89	0.89	25.02**	2.78	42.86*	28.33
Polf-14 x Polf-22	19.81*	-1.60	3.84**	3.69	31.41**	2.61	32.71*	40.34
Polf-14 x T-397	26.04**	16.79	2.61	2.55	31.18**	4.72	31.39	10.57
Polf-14 x SIKO-10	23.34**	32.02	-1.11	-1.12	15.58**	13.51	70.28**	41.76
Polf-22 x T-397	29.50**	20.51	1.24	1.22	9.51	10.05	-8.33	15.91
Polf-22 x SIKO-10	7.11*	7.18	-2.15	-2.19	6.49	3.00	8.33	27.50
T-397 x SIKO-10	-4.13	0.00	0.00	0.00	10.25*	6.40	9.17	11.70

Name of the cross	No. of secondary branches/plant		No. of capsules/plant		No. of seeds/capsule		1000 seed weight (g)	
	Het(BP)	ID%	Het(BP)	ID%	Het(BP)	ID%	Het(BP)	ID%
Kiran x R-552	132.33**	53.05	132.40**	51.80	0.00	-0.57	12.47*	10.98
Kiran x LCK-88062	110.47**	58.79	155.49**	50.14	0.00	20.37	-0.62	7.18
Kiran x T-397	36.65	38.56	66.06**	38.49	-22.33*	6.34	27.83**	5.93
R-552 x LCK-88062	62.99*	42.07	116.01**	48.18	-21.62*	-4.14	8.43	23.86
R-552 x T-397	25.82	52.46	126.93**	69.01	-30.73**	-2.25	7.63	9.29
LCK-88062 x T-397	249.74**	77.69	17.91**	16.94	-36.37**	-37.73	4.07	15.36
Polf-14 x Polf-22	16.59	38.48	62.93**	47.23	13.05	-5.34	-7.49	10.36
Polf-14 x T-397	0.00	28.37	62.81**	57.28	-9.60	11.42	18.44**	13.73
Polf-14 x SIKO-10	50.88	24.28	102.32**	61.69	-28.24**	-56.79	7.18	10.79
Polf-22 x T-397	-12.39	12.09	36.00*	26.31	-21.13*	-0.91	2.95	9.86
Polf-22 x SIKO-10	18.55	41.15	69.73**	54.92	-8.29	-7.46	4.03	9.76
T-397 x SIKO-10	-2.32	28.69	62.56**	52.99	-33.61**	-33.27	30.86**	21.54

Name of the cross	No. of seeds/plant		Harvest index (%)		Seed yield/plant (g)	
	Het(BP)	ID%	Het(BP)	ID%	Het(BP)	ID%
Kiran x R-552	81.21**	45.69	43.42**	20.37	120.99**	55.42
Kiran x LCK-88062	187.99**	37.76	11.31	2.97	264.11**	48.89
Kiran x T-397	39.49**	5.69	-6.07	-6.46	88.10**	11.95
R-552 x LCK-88062	65.54*	25.20	-12.85	-14.75	99.80**	44.31
R-552 x T-397	51.54**	50.70	-7.69	-8.33	92.68**	50.65
LCK-88062 x T-397	24.29	4.3	-26.90**	-36.80	95.54**	19.47
Polf-14 x Polf-22	61.97**	39.66	-0.70	-0.71	72.38**	50.39
Polf-14 x T-397	33.83*	41.00	-11.59	-13.11	69.10**	52.14
Polf-14 x SIKO-10	110.29**	58.02	2.89	2.81	127.26**	64.02
Polf-22 x T-397	53.79**	31.14	2.97	2.89	113.85**	38.82
Polf-22 x SIKO-10	64.04**	42.29	6.79	6.35	93.46**	52.52
T-397 x SIKO-10	16.16	36.85	-6.28	-6.69	61.94**	48.99

Het (BP) = Heterosis over better parent; ID = Inbreeding depression

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J. Oilseeds Res., **23**(2) : 191-193 (2006)

Assessment of genetic diversity in niger, *Guizotia abyssinica* (L.) Cass

R.V. Sreedhar, S. Gangaprasad, R.L. Ravikumar and P.M. Salimath

Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad-560 005, Karnataka

(Received: June, 2005; Revised: December, 2005; Accepted: January, 2006)

Abstract

One hundred germplasm accessions were used to assess the nature of genetic diversity in Niger, *Guizotia abyssinica* (L.) Cass by using Mahalanobis' D^2 statistics using all the 10 characters studied. Plant height, days to 50% flowering and days to maturity were observed to be the major contributors to the genetic divergence in the germplasm. Grouping of genotypes into clusters using Tocher's method resulted in formation of seven clusters. Maximum intracluster distance was shown by cluster IV while clusters I and II showed highest inter cluster distance.

Key words: *Guizotia abyssinica*, D^2 statistics, genetic divergence

Introduction

Niger is an important minor oilseed crop cultivated in India on an area of 0.45 million ha with a production of 0.11 million tones Giriraj (2003). Seeds contain 35 to 40% oil which is of high quality and is mainly used for culinary purpose, manufacture of cosmetics, soaps, paints, lubricating and lighting. Oilseed meal is used as cattle and poultry feed.

In earlier days, morphological dissimilarity, eco-geographical diversity, phylogenetic relationship and other criteria were used in discriminating any divergent population. Later, a method utilizing multiple measurements which are subjected to multivariate analysis based on generalized distance as indicated by D^2 statistic proved to be worth in quantifying the degree of divergence between populations (De *et al.*, 1988; Biswas and Samsal, 1990). The task of breeding for better varieties needs generation of genotypes with desirable attributes. Getting such genotypes basically depends on choice of genetically distant parents for hybridization. Selection of parents based on the extent of genetic diversity was successfully utilized for genetic improvement of different crops. In the present study, an attempt was made to know the genetic divergence among the 100 germplasm accessions through Mahalanobis D^2 statistics.

Material and methods

The material used for the present study comprised of 100 germplasm lines obtained from AICRP on Sesame and Niger, Jabalpur. A field experiment to study genetic variability was laid out in simple Lattice Design with two replications at Department of Genetics and Plant Breeding, College of Agriculture, Dharwad during *kharif* 2002. Each replication consisted of 10 sub-blocks each having 10 varieties of one line each. Each variety was allotted at random in each sub-block. Each treatment was grown in a single row of 3 m length with a spacing of 30 x10 cm. All recommended agronomic practices were followed during the crop growth period. Five plants were tagged at random in each replication. The observations were recorded on days to 50% flowering, days to maturity, plant height, number of primary branches/plant, number of capitula, capitulum diameter, number of seeds/capitulum, seed yield/plant, test weight and harvest index. The genetic divergence was estimated using Mahalanobis D^2 statistics (1936).

Results and discussion

All 100 genotypes used for the study were grouped into seven clusters based on D^2 statistics (Table 1). Inter cluster D^2 values ranged from 74.02 to 227.96. The intra cluster distance showed range from 0 (solitary cluster) to 39.94.

The analysis for estimating the contribution of various traits towards expression of genetic divergence revealed that plant height, days to 50% flowering and days to maturity were the major contributors. Seed yield/plant and harvest index made negligible contribution. Earlier Anand and Chandra (1980) reported that sunflower genotypes had shown the flowering time as the major contributor to genetic diversity. Sankarapandian *et al.* (1996) have concluded that days to 50% flowering and plant height contributed more to the genetic diversity in sunflower. A study of genetic diversity in niger by Sohanram and Kerketta (1998) has revealed that days to maturity and plant height were major contributors and days to flower also contributed substantially to the genetic diversity. The present observations made are in accordance with the above conclusions. Same study also revealed that capitulum diameter also made a notable contribution along with a substantial contribution of yield/plant and number of branches. These contradictory reports may be due to use of different kind of material for studies. Studies of Manjula (1997) in sunflower also supported the results

that plant height is a major contributor to genetic diversity with significant contribution from days to 50% flowering.

It was observed that genotypes forming cluster I (17 entries) were genetically more divergent from those in all other clusters except genotype in cluster VII (GA-23) (Table 2). Other cluster combinations with very high intercluster D2 values were II and III, II and IV, II and VII, III and IV, III and V, III and VI, IV and V, IV and VII, V and VI, V with VII and VI with VII. Rest of the cluster combinations can be considered as less divergent ones looking into their D^2 values.

Cluster V was found to be superior with respect to seed yield/plant along with other desirable traits like higher plant height, higher number of capitula/plant, higher number of seeds/capitulum, higher test weight and higher number of primary branches at harvest. But, genotypes of this cluster were of late maturing type with low capitulum diameter and harvest index. Genotype constituting cluster VI was found to be having desirable characters like early flowering, early maturation, higher capitulum diameter and a higher harvest index. Inter crossing between genotypes belonging to cluster V and cluster VI may generate large variability and can be expected to produce desired genotypic combinations and transgressive segregants and form a good source material in population improvement programme (Table 3).

Table 1 Clustering pattern of 100 germplasm of niger

Cluster	No. of entries	Entry
I	17	GA-24, 25, 26, 27, PHW-2004-2, No.1, 5, 14, 36, CH-4, 7, EC-158670, 158671, 158672, 158673, NC-63587, 63592
II	23	N-2, 4, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 28, 29, 30, 32
III	27	5-28, 5-64, 5-78, 11-5, 18-64, 22-63, 34-14, 41-50, 41-52, 52-26, 61-30, 65-26, 71-14, 78-23, 82-8, GA-1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 15, 22
IV	27	N-34, 35, 36, 37, 38, 46, 47, 48, 49, 50, 51, 52, 57, 58, 70, 71, 75, 76, 79, 80-8, 87-14, BHC-120, Comp-II, 5-1, 5-4, 5-6, 5-9
V	4	N-25, 26, 27, 31
VI	1	N-33
VII	1	GA-23

Table 2 Inter and intra cluster distance values for 7 clusters with 10 characters in niger

Cluster	I	II	III	IV	V	VI	VII
I	**30.303**	227.959	178.198	201.257	220.825	203.741	99.412
II		**38.699**	187.981	180.019	74.020	84.681	188.296
III			**32.728**	178.937	211.930	172.053	84.128
IV				**39.936**	201.017	101.808	168.015
V					**11.975**	113.687	195.669
VI						**0.000**	165.844
VII							**0.000**

Diagonal values indicate intra cluster distance; Above diagonal values indicate inter cluster distance

Table 3 Cluster mean values for 10 different characters in niger

Cluster	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
I	156.706	14.765	55.176	63.118	86.618	1.065	30.735	3.576	2.279	0.088
II	143.783	13.348	55.326	61.565	85.956	1.017	24.261	3.583	1.994	0.079
III	140.148	11.482	46.815	63.389	86.704	1.041	22.167	3.333	1.113	0.080
IV	153.592	16.388	56.093	62.148	86.444	1.055	28.481	3.496	3.031	0.090
V	169.625	19.125	114.000	63.000	86.500	1.225	47.875	3.983	4.225	0.098
VI	169.500	15.500	44.500	56.500	84.500	1.350	31.500	3.900	3.000	0.120
VII	160.500	16.000	52.000	62.500	89.000	1.000	24.500	3.430	3.150	0.050

X_1 - *Plant height (cm)*
X_2 - Number of primary branches
X_3 - Number of capitula per plant
X_4 - Days to 50% flowering
X_5 - Days to maturity
X_6 - Capitulum diameter (cm)
X_7 - Number of seeds per capitulum
X_8 - Test weight (g/1000 seeds)
X_9 - Seed yield per plant (g)
X_{10} - Harvest index (%)

It is worthy to note that *in arriving cluster mean*, the superiority of a particular genotype in respect to given character gets diluted by other genotypes that are related and *grouped in the same* cluster which are inferior or intermediary for that character in question. Such trend was observed in performance of genotypes N-23 and N-30 compared to mean performance of their cluster II. Same thing was also noted in performance of genotype 41-52, which was away from mean performance of its cluster III. Hence, apart from selecting lines from the cluster which have high inter cluster distance for hybridization, one should think of selecting parents based on the extent of divergence in respect to a character of interest i.e., if breeders intention is to improve plant height, he should go for selecting parents which are *highly divergent with* respect to this trait. Apart from this the most productive lines which are divergent among themselves may be involved *in population improvement*.

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J. Oilseeds Res., 23(2) : 194-198 (2006)

A functional approach to predict effects of water deficits in groundnut, *Arachis hypogaea* L.*

S. Hemalatha, V. Praveen Rao and B.N. Reddy[1]

Dept. of Agronomy, College of Agriculture, ANG Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, AP

(Received: March, 2005; Revised: October, 2005; Accepted: December, 2005)

Abstract

An experiment was conducted to study the response of groundnut to evapotranspiration deficits imposed at specific crop growth periods by imposing four irrigation levels i.e., fully irrigated control (I_1), moisture stress at flowering and pegging (I_2), moisture stress at pod initiation and addition period (I_3) moisture stress at pod filling period (I_4). The crop in fully irrigated control treatment produced maximum mean pod yield of 2830 kg/ha. Evapotranspiration deficits (moisture stress) at various crop growth periods caused significant reduction (16.4 to 20.6 %) in pod yield relative to fully irrigated control. Pod yield reduction due to evapotranspiration deficits at flowering and pegging period was 20.6% below maximum yield (Ym) with a yield sensitivity coefficient of 1.7. The groundnut crop at flowering and pegging period was 11.5% and 19.7% more sensitive to evapotranspiration deficits than in pod initiation and pod addition period and pod filling period respectively. The relative sensitivity of groundnut to water deficits was found to be highest in flowering and pegging period, moderate in pod initiation and addition and least in pod filling period.

Key words: Groundnut, evapotranspiration deficits, yield sensitivity coefficient

Introduction

As the pressure for efficient use of water in agriculture is mounting there is need for greater emphasis on environmentally friendly irrigation practices. Further irrigated agriculture is entering on "age of management" in which water deficits during crop growing season may not be avoided totally, but instead favorably controlled. Irrigation planning in future, therefore, is more likely to be based on purposeful imposition of water deficits during crop season controlled both in intensity and time i.e. optimal sequencing of evapotranspiration (Eta) deficits to meet specific objectives. Thus development of functions to quantitatively predict in advance of planting the effects of water deficits during crop growing season on crop yield would help in rational management of available limited water supplies.

Groundnut an important oilseed crop cultivated during *rabi* season under irrigated conditions is often subjected to water deficits causing heavy yield depressions. The present study was therefore designed to quantify the relative sensitivity of crop to water deficits at specific crop growth periods for optimal allocation of limited water supplies to minimize yield losses under scarce water supply situation.

Material and methods

The field experiment was conducted on a sandy loam soil during the *kharif* and *rabi* seasons of 1997-98 and 1998-99 at the college farm of Acharya N G Ranga Agricultural University, Hyderabad (17°19'N, 78° 23'E and 542.3 m above mean sea level).

The treatments included were four phosphorus levels i.e., 0, 30, 60 and 90 kg P_2O_5/ha to sunflower during *kharif*, combination of residual P (0, 30, 60 and 90 kg P_2O_5/ha applied to sunflower and four irrigation levels (I_1, I_2, I_3 and I_4) as main plots and four direct P levels (0, 30, 60 and 90 kg/ha) as subplots to groundnut during *rabi* season. The irrigation treatments comprise -fully irrigated control (I_1), moisture stress at flowering and pegging (I_2), moisture stress at pod initiation and addition period (I_3) and moisture stress at pod filling period (I_4). The details of the same are given in Table 1. Thus constituted four treatments in sunflower were tested in Randomized Block Design with twelve replications during *kharif* season and 64 (4x4)x4 treatments in groundnut were tested in Split Plot Design with three replications during *rabi* season. In any given growth sub period, the crop in a given treatment was either irrigated based on soil-crop climatic data (Table 1) to ensure Eta proceeded at the potential rate (Etm) nor irrigated during particular crop growth stage. For stress treatments (I_2, I_3 and I_4) after relieving of stress

[1]Principal Scientist (Agronomy), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP.

* Part of Ph.D. Thesis work carried out by the first author.

the irrigation schedule as that of I_1 (Eta=Etm) was followed, following an Etd in water deficit treatment at the end of the crop growth sub period the root zone depth of the crop was replenished to field capacity (-0.03 Mpa) moisture content. A 50 mm water meter was installed to deliver the required quantity of water in each plot. Groundnut cv. ICGS-11 was sown by dibbling during both the seasons on 20-10-97 and 2-11-98 respectively by adopting a spacing of 30x10 cm. Other recommended agronomic practices were followed. The crop was subjected to moisture stress by with holding water at different crop growth sub periods. The ground water table was below six meters during the crop-growing season; hence, it is assumed that there was not any contribution from groundwater table towards crop water needs.

For determination of crop Eta, the soil moisture was monitored by gravimetric method at four locations and at various depths in each treatment from surface to 60 cm soil depth before and after each irrigation and no intermediate dates as necessary (Table 2). The reference crop evapotranspiration (Eto) was estimated at specific crop growth sub-periods based on Hargreaves method (Hargreaves and Samani, 1982).

The experimental soil had N, P_2O_5 and K_2O at 255, 11.2 and 472 kg/ha respectively with pH 7.5, bulk density 1.66 g/cm^3 and EC 0.12 dS/m. The available soil moisture determined as difference between moisture held at -0.03 Mpa (field capacity) and -1.5Mpa (permanent wilting point) was 84.4 mm in 60 cm soil profile.

To quantify the effect of Eta deficits on yield relationship between relative yield reduction and relative evapotranspiration deficit was worked out by regression analysis as suggested by Stewart *et al.*(1977).The relationship is as follows:

$$Ym-Ya/Ym=Ky(Etm-Eta/Etm)$$

Where Ym=maximum pod yield in fully irrigated control i.e., I_1 treatment
Ya=actual pod yield of the crop as affected by Eta deficits
Etm=seasonal evapotranspiration of fully irrigated crop
Eta=seasonal evapotranspiration in water deficit treatments
Ky=yield sensitivity factor

The crop was harvested on 11.2.1998 and 3.3.1999 in the first and second year respectively. The water use efficiency (kg/ha-mm) was calculated as a ratio between pod yield and seasonal evapotranspiration.

Results and discussion

Effect of water deficits on crop ETa, yield and water use efficiency of groundnut: The seasonal crop ETa in fully irrigated control, I_1 treatment exceeded the crop ETa registered in other treatments. Withholding of irrigations during individual crop-growth sub-periods in stress treatments *viz.*, I_2 (moisture stress at flowering and pegging period), I_3 (moisture stress at pod initiation and addition period) and I_4 (moisture stress at pod filling period) caused appreciable reduction in ETa relative to fully irrigated control I_1 treatment. Thus a seasonal ETa deficit of 39.9 mm, 43.3 mm and 40.2 mm in 1997-98 and 47.4 mm, 47.9 mm and 43.1 mm in 1998-99 was observed in I_2, I_3 and I_4 treatments, respectively relative to I_1 treatment (Table 2). The ratio of ETa/ET0 (Kc value) value indicates the degree of water deficit at which water uptake of a crop begins to be limited. With holding of irrigation during specific crop growth periods (I_2, I_3 and I_4) caused marked reduction (65.6 mm to 307.55 mm in 1997-98 and 71.5 mm to 336.2 mm in 1998-99) in seasonal Eta relative to I_1 treatment. Thus the ratio of ETa/ETo in I_1 treatment approximated 1.0 from flowering to the start of pod filling period indicating that the crop in this treatment was able to extract adequate amount of water relative to evaporative demand of the atmosphere. However the crop in I_4 treatment though extracted water sufficiently up to start of pod filling period, subsequently due to withholding of irrigations experienced ETa deficits as was evident from sudden drop in ETa/ETo ratio during later part of the crop growing season. There is evidence that soil water deficits developed due to withholding of irrigation reduce both seasonal ETa and ETa rate during the crop-growing season (Ramachandrappa and Kulkarni, 1992).

The crop in fully irrigated field (I_1) produced significantly higher pod yield in both the years (2757 kg/ha in 1997-98 and 2903 kg/ha in 1998-99 and on pooled basis 2830 kg/ha)(Table 3). Evapo-transpiration deficits at individual crop growth periods caused significant reduction (16.4 to 20.6%) in pod yield relative to I_1 treatment in both the years and on pooled basis. The better performance of the crop in I_1 could be traced to favorable soil water balance in these treatments as evidenced from the Eta values and Eta/Eto ratios. The ratio of Eta/Eto value indicates the degree of water deficit at which water extraction by a crop begins to be limited. According to Vijay Kumar and Praveen Rao (2003) the Eta/Eto ratio of a non-stressed sunflower crop should approximate >1.0 after canopy closure. Thus, the ratio of Eta/Eto in I_1 treatment approximated 1.0 from flowering to start of maturity period (Table 4) indicating that the crop in this treatment was able to extract the highest amount of water relative to evaporative demand of the atmosphere. With holding of irrigations during reproductive growth period *viz.*, flowering and pegging period, pod initiation and addition period and pod filling period caused Eta to fall below Etm in I_2 treatment (moisture stress at flowering and pegging period), I_3 (moisture stress at pod initiation and pod addition period) and I_4 (moisture stress at pod filling period) treatments inducing soil water deficits in the crop root zone. This unfavorable soil moisture condition

brought about significant reduction in yield contributing characters like no. of pods/plant, matured pods/plant, 100- kernel weight, shelling percentage and harvest index through reduction in photosynthetically active leaf area. The crop in I_2, I_3 and I_4 experienced moderate to severe Eta deficits as evident from low Eta/Eto ratios in these treatments causing significant reduction in pod yield.

The fully irrigated control (I_1) recorded higher water use efficiency values during both the years (Table 3). Provision of favourable soil water balance duly accounting for evaporative demand of the atmosphere (Eta/Etm =1) was shown to enable in effective use of water contributing to higher pod yield as well as water use efficiency as is evident from the fully irrigated control I_1 treatment in the present study. On the other hand Eta deficits at crop growth periods of flowering and pegging, pod initiation and addition and pod filling period caused significant reduction in water use efficiency as is evident from I_2, I_3 and I_4 treatments owing to appreciable reduction in pod yield relative to Eta reduction in respective treatments (Reddy, 1988).

Sensitivity of pod yield of groundnut to Eta deficits: To examine the sensitivity of pod yield of groundnut to evapotranspiration deficits the Stewart's S_2 function was adopted and resultant yield response sensitivity coefficient (Ky) for specific crop growth sub periods were determined by regression analysis and presented in Table 5.

The test statistic R^2 indicated that the explained total variation in relative pod yield deficit varied between 0.995 to 0.998 in 1997-98, 0.989 to 0.996 in 1998-99 and 0.986 to 0.996 on pooled basis under different treatments. The R^2 values were highly significant (P=0.01) in both the years and on pooled basis. This implies that the function is statistically acceptable concerning fitting of the observed data considering the time of Eta deficit at specific crop growth periods.

The Ky values which reflect the relative sensitivity of pod yield to Eta deficit varied with the crop growth period and with the magnitude of Eta deficit imposed at various crop growth periods, were positive and significantly different from zero.

Comparison of Ky values in I_2 (Eta deficits at flowering and pegging period), I_3 (Eta deficits at pod initiation and pod addition period) and I_4 (Eta deficit at pod filling period) treatments indicated that the relative yield decrease for a given level of Etd was least in pod filling, intermediate in pod initiation and addition period and highest in flowering -pegging period. The data on Ky values in Table 5 for I_2, I_3 and I_4 suggests us that the flowering-pegging period in groundnut is inherently about 0.16 (16.04 %) and 0.2699 (26.99 %) times in 1997-98, 0.074 (7.4 %)and 0.135 (13.5%) times in 1998-99 and 0.115 (11.5 %) and 0.197 (19.7) times on pooled basis more sensitive to Eta deficits than in pod initiation and addition period and pod filling period respectively. Like wise, the pod initiation and addition period of groundnut was 0.094 (9.4 %) in 1997-98, 0.056 (5.6 %) in 1998-99 and 0.073 (7.3 %) times on pooled basis more sensitive to Eta deficits than in pod filling period.

The potential yield of groundnut (Ym=kg/ha) on pooled basis was obtained when the crop was fully irrigated at Eta/Etm=1 throughout the crop growing season. The high yield obtained in I_1 treatment also indicates the accuracy and reliability of empirical methodology adopted for calculation of irrigation water depth and irrigation interval for the groundnut in the present study.

A significant decrease in pod yield was observed in remaining treatments *viz.*, I_2, I_3 and I_4 where there was an Eta deficit at individual crop growth sub periods. Pod yield reduction due to Eta deficits at flowering and pegging period amounted to 20.6 % below Ym with a yield sensitivity coefficient of 1.6375 on pooled basis. This is understandable since moisture stress during this period inhibits flowering as well as peg penetration in to the soil, ultimately limiting the mature pod number per plant. Likewise Eta deficits at I_3 and I_4 lead to significant reduction in pod yield and resulted in a sensitivity coefficient of 1.5003 and 1.3975 respectively.

Table 1 Determination of irrigation requirement for groundnut in fully irrigated treatment based on soil-crop-climatic parameters

Crop growth period	Duration days	Eto mm/day	Kc	Etm mm/day	Rooting depth 'D' cm	Sa.D (cm)	P (fraction)	I=Sa. D.P/ETm	IRR mm
Vegetative	31.0	3.02	0.75	2.27	45	63.3	0.7	19.5	43.92
Flowering and pegging	26.0	2.78	1.025	2.84	60	84.4	0.59	17.5	49.98
Pod initiation and pod addition	28.5	3.46	1.025	3.58	60	84.4	0.59	14.0	49.76
Pod filling and maturity	33.0	4.61	0.80	3.68	60	84.4	0.625	14.5	53.28

Table 2 Evapotranspiration (mm) of groundnut as influenced by different levels of irrigation at different stages of crop growth

Treatment	Vegetative		Flowering to pegging		Pod initiation and addition		Pod filling and maturity		Total growing season	
	1997-98	1998-99	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99
I_1	76.5	66.5	70.9	76.7	82.4	108.9	108.6	118.7	338.4	370.8
I_2	74.7	67.3	51.5	62.5	69.8	86.8	102.5	106.8	298.5	323.4
I_3	77.8	63.0	69.5	72.0	63.6	80.4	84.2	107.5	295.1	322.9
I_4	76.0	65.6	70.5	75.8	80.9	105.6	70.8	80.7	298.2	327.7

I_1 Fully irrigated control(Irrigation at Eta/Etm = 1 through out the crop growing season)
I_2 With holding of irrigations at flowering and pegging period (24-28 days)
I_3 With holding of irrigations at pod initiation and pod addition period (27-28 days)
I_4 With holding of irrigations at pod filling period (32-34 days)

Table 3 Pod yield (kg/ha) and water use efficiency of groundnut as influenced by different treatments

Treatment	Pod yield (kg/ha)		Water use efficiency (kg/ha mm)		
	1997-98	1998-99	Pooled	1997-98	1998-99
I_1	2757	2903	2830	8.18	7.83
I_2	2186	2309	2247	7.33	7.16
I_3	2223	2344	2283	7.54	7.28
I_4	2304	2427	2365	7.74	7.43
SEm±	18.00	27.00	21.00	0.12	0.14
CD (P=0.05)	55.00	80.00	62.00	0.35	0.42

Table 4 Eta/Eto ratios of groundnut as influenced by evapotranspiration deficits at various growth sub-periods

Treatment	Vegetative		Flowering and pegging		Pod initiation and pod addition		Pod filling and maturity		*Total growing period*	
	1997-98	1998-99	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99
I_1	2.55	2.08	2.95	2.74	3.05	3.63	3.19	3.71	2.94	3.04
I_2	2.49	2.10	2.15	2.23	2.59	2.89	3.02	3.34	2.60	2.65
I_3	2.59	1.97	2.90	2.57	2.36	2.68	2.48	3.36	2.57	2.65

Table 5 *Empirical estimates* for the relationship between relative yield deficit and relative evapotranspiration deficit for groundnut in different treatments

Treatment	Regression *constants, coefficients and test statistics*		
Moisture stress at	Intercept(a)	Yield sensitivity factor (Ky)	Coefficient of determination
Flowering and pegging period (I_2)	0.00001	1.6735**	0.986**
Pod initiation and pod addition period (I_3)	0.00001	1.5003**	0.989**
Pod filling period (I_4)	0.00001	1.3976**	0.996**

Conclusion: Thus based upon yield response sensitivity coefficients (Ky) it can be deduced that the relative sensitivity of groundnut pod yield to moisture stress is highest in flowering and pegging period, moderate in pod initiation and addition period and least during the pod filling period. It follows that the Ky values for treatments I_2, I_3 and I_4 on pooled basis indicate that the groundnut crop at flowering and pegging period is inherently 11.54% and 19.74% more sensitive to eta deficits than in pod initiation and addition period and pod filling period respectively. Like wise the groundnut crop in pod initiation and addition period was 7.34% more sensitive to eta deficits than in pod filling period on pooled basis. Such quantification of yield reduction to eta deficits at individual crop growth sub periods and development of yield sensitivity coefficients will enable the groundnut farmers in allocation of available limited water supplies to crop growth sub periods where in the response is highest leading to maximization of productivity per unit amount of water.

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J. Oilseeds Res., 23(2) : 199-204 (2006)

Effect of moisture conservation, nutrient and cultivar on productivity of rainfed groundnut, *Arachis hypogaea* L.

Devi Dayal, P.J. Gohil and B.N. Reddy[1]

National Research Centre for Groundnut, Post Box No. 5, Junagadh-362 001, Gujarat

(Received: February, 2006; Revised: April, 2006; Accepted: June, 2006)

Abstract

On-farm trials were conducted during rainy season of 2001-02 at Junagadh (Gujarat) to study the effect of moisture conservation and nutrient on yield and economics of Virginia and Spanish groundnut (*Arachis hypogaea* L.). The results revealed that yield and economics of groundnut varied significantly due to year and treatment. In low and scanty rainfall year of 2002, improved method of moisture conservation (opening of furrow after every third row) along with recommended dose of fertilizer gave significantly higher pod and oil yields by 13.8 and 30.6% in Virginia cultivar and 12.3 and 20.8% in Spanish cultivar, respectively over the farmers' practice. This improved technology also gave higher net returns (Rs. 27040 to 23767/ha) and more BCR (3.42-3.60) compared with the farmers practice. Among the cultivars, GG 13 in Virginia and GG 5 in Spanish proved superior to local cultivar (GAUG 10 and J 11) in terms of yield and net returns. Rain water use efficiency was the maximum when GG 13 (Virginia) or GG 5 (Spanish) was grown under improved method of moisture conservation and fertilizer application.

Key words: Groundnut, moisture conservation, nutrient, cultivar and rainfed

Introduction

In rainfed cultivation, maintenance of optimum soil moisture especially at critical growth stages is the key factor for realizing higher productivity. Groundnut, predominantly grown as rainfed crop in the country, suffers from severe moisture stress at one or several stages of its growth because of inadequate and uneven distribution of rainfall during the crop season. Though attempts have been made to develop efficient technologies for conserving *in situ* moisture in rainfed groundnut (Nalawade and More, 1993; Sandhya *et al.*, 1994; Khistria *et al.*, 2003), the rate of adoption of these technologies by the farmers remains notably low and is still insufficient to have a real impact on rainfed cultivation. Evaluating these moisture conservation techniques without taking into consideration of cultivar and nutrient supply in the soil perhaps was the main reason behind such a low impact of these technologies on the real farming situations. This suggests the need for taking more comprehensive approach while developing *in situ* moisture conservation practice for rainfed farming. Hence, a field experiment on moisture conservation techniques along with nutrient and cultivar was conducted on the farmers' fields under real farming situations in Saurashtra region of Gujarat.

Material and methods

The experiment was conducted on the farmers' fields in two villages of Junagadh district, Gujarat during rainy season of 2001 and 2002. Twenty farmers' fields were selected each year for the experimentation. The soil of the experimental site was black calcareous in nature (Ustrochrept vertisols) and low in available nitrogen, phosphorus and medium in available potash. Twenty field experiments, ten each for Spanish and Virginia cultivars of groundnut were conducted adopting Split Plot Design. The main plot treatment consisted of three levels of moisture conservation and fertilizer application, *viz.*, M_1 : farmers method of moisture conservation (repeated harrowing) and fertilizer application (50 kg DAP/ha); M_2 : farmers method of moisture conservation and recommended dose of fertilizer (RDF, 12.5-25-0 kg N, P_2O_5 and K_2O/ha) and M_3 : RDF and recommended method of moisture conservation (Opening a moisture conservation furrow after every third row). The sub-plot treatment were three cultivars each of Spanish (V_1 : J 11-local cultivar; V_2 : GG 2 most common cultivar and V_3 : GG-5 recently released) and Virginia (V_1 : GAUG 10-local; V_2 : GG 20-most common and V_3 : GG 13-recently released). The gross plot size was 200 m^2. The experiment was sown in second fortnight of June in both the years. All other management practices were adopted as per the recommendations for rainfed groundnut for the region.

The rainfall during the crop growth period (June to December) in 2001 was 826.9 mm which was received in 47 rainy days compared with 540.3 mm in 22 rainy days during 2002. Thus, in 2002, the crop was subjected to

[1] Principal Scientist (Agronomy), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, A.P.

about one month soil moisture stress during its early growth stage as only 45 mm of rainfall was received in the month of July. Similarly, there was a severe moisture stress during its pod development stage in the month of September where only 93 mm of rainfall in just 2 rainy days was received. In general, the crop was free from insect pests and diseases during both the years. The crop was harvested in the month of October (Spanish) and November (Virginia) in both the years. At the time of harvesting, the yield attributing parameters were recorded on 5 plants and pod and haulm yields were recorded on plot basis. Oil yield was computed based on oil content in the kernel and kernel yield. Economics was worked out based on prevailing market price of the produce. Rain water use efficiency was computed by dividing pod yield with total rainfall received in the crop growth period. The pooled analysis of the data was done as per method described by Gomez and Gomez (1983) where each farmer's field was considered as replication. Since, the interaction of treatment x year was found to be significant for most of the parameters, the data were presented and discussed year-wise.

Results and discussion

Effect of year: In general rainfall was more ideal for growth and development of groundnut in 2001 compared with 2002 that resulted in significantly higher pod and oil yields by about 14.7-14.8% in Virginia cultivars and 28.6 to 40.4% in Spanish cultivars, respectively. Though, haulm yield and net returns were not influenced by the year, cost benefit ratio (CBR) was significantly higher in Spanish cultivar in the year 2001 (3.2) than in 2002 (3.1). Improved yield attributes especially number and weight of pods/plant along with 100 seed weight in Virginia, and 100 seed weight along with shelling in Spanish cultivar resulted in higher yields during favourable year of 2001 compared with the year 2002 when crop faced severe moisture stress both at growth and reproductive phases. Rao (1996) reported that periodic drought due to insufficient and uneven distribution of rainfall was one of the important factors limiting yields in rainfed groundnut.

Yield attributes and yield

a) Yield attributes: Moisture conservation and fertilizer did not influence significantly the yield attributes in both Virginia and Spanish cultivars during the favourable year 2001, except 100 seed weight in Virginia cultivar (Table 1). Obviously, well distributed rainfall (49 rainy days) over the crop growth period helped in maintaining proper soil moisture at the root zone of the crop which nullified the favourable effect of moisture conservation practices. However, in 2002, recommended moisture conservation and fertilizer (M_3) improved significantly all the yield attributes, except pods/plant in Virginia and 100 seed weight in Spanish cultivars compared with the farmer's method of moisture conservation and fertilizer (M_1). Application of recommended dose of fertilizer without adopting moisture conservation (M_2) did not have significant impact on yield attributes. Sandhya *et al.* (1994) observed that opening of plough furrow either at 30 or 60 cm conserved moisture and produced more pods with heavier seeds than that under no soil moisture practice in rainfed groundnut.

Cultivar differed significantly for yield attributes in year 2002. Cultivar GG 13 in Virginia and GG 5 in Spanish had significantly more and heavier pods/plant, higher seed weight and shelling, closely followed by GG 20 (Virginia) and GG 2 (Spanish) than that recorded by respective local cultivars (GAUG 10 and J 11). In 2001, though Spanish cultivar did not differ significantly, Virginia cultivar GG 20 had significantly higher number and weight of pods/plant and 100 seed weight than those in GAUG 10 and GG 13. Better performance of GG 13 in moisture stress year of 2002 suggests some degree of drought tolerance compared with GAUG 10 and GG 20. Differential response of groundnut cultivars to moisture stress was also reported by Joshi (1985).

b) Yield: Pod, haulm and oil yields differed significantly only in year 2002 due to moisture conservation and fertilizer (Table 2). The improved moisture conservation and recommended fertilizer (M_3) produced higher pod, haulm and oil yields by 13.8, 18.4 and 30.6%, respectively compared with the farmers practice (M_1) in Virginia cultivar. The corresponding figures for Spanish cultivar were 12.3, 8.0 and 20.8%, respectively. Vigorous growth, more and heavier pods coupled with more 100 seed weight under M_3 resulted in higher pod, haulm and oil yields compared with the farmers practice (M_1). Also, better availability of moisture and nutrient in the root zone under M_3 compared with M_1 might have facilitated more nutrient uptake resulting in improved yield attributing parameters and finally yields. These results conformed to those reported by Sandhya *et al.* (1994) and Khistria *et al.* (2003).

Virginia cultivar differed significantly in both the years and pooled; except for haulm yield in 2001 whereas, Spanish cultivar differed significantly only in 2002 for yields. Virginia cultivar GG 20 produced significantly higher pod yield (30.1%) and oil yield (39.6%) compared with GAUG 10 in 2001. However, in 2002, GG 13 have maximum and significantly higher pod yield by 11.8%, haulm yield by 11.2% and oil yield by 16.3% over the GAUG 10, but remained statistically at par with cultivar GG 20 for oil *yield. On pooled basis, GG 20 proved superior to both,* GAUG 10 and GG 13 by registering higher pod yield by 19.5 and 17.3% and oil yield by 27.2 and 22.4%, respectively. Spanish cultivar GG 5 proved significantly

superior to both the remaining cultivars, J 11 and GG 2, for pod and oil yields and to J 11 for haulm yield by producing higher pod yield by 19.3-8.0%, oil yield by 22.8-5.3% and haulm yield by 12.5%, respectively. Biswas and Sharma (2005) reported that an integrate approach for soil moisture conservation, nutrient and improved cultivar increased pod yield of groundnut by 60% over the farmers practice.

Rain water use efficiency: Rain water use efficiency (RUE), a measure of effectiveness of rainfall for crop production, varied significantly due to year and treatment (Fig. 1). It was significantly higher (3.417-3.775 kg/ha/mm) in 2002 than in 2001 (2.830-2.871 kg/ha/mm). Some of the parts of high rainfall in 2001 (826.9 mm) might have lost as a run off during the crop growth period and did not contribute to consumptive use of water of the crop resulting in low rain water use efficiency compared with that in 2002 (540.3 mm). In 2001, RUE due to moisture conservation and fertilizer did not vary significantly. However, Virginia cultivar GG 20 and Spanish cultivar GG 2 recorded significantly higher RUE, irrespective of moisture conservation and fertilizer treatments. The maximum RUE of 3.691 kg/ha/mm was recorded by Virginia cultivar GG 20 under M_3 treatment. Cultivar GG 13 recorded the minimum RUE of 2.30 kg/ha/mm. In Spanish group, cultivar GG 2 under M_3 recorded the maximum (3.201 kg/ha/mm) and J 11 under M_3 the minimum (2.607 kg/ha/mm).

Table 1 Yield attributes of groundnut as influenced by different treatments

Treatment	Pod/plant		Pod weight/plant (g)		100 seed weight (g)		Shelling (%)	
	2001	2002	2001	2002	2001	2002	2001	2002
Virginia cultivar								
Moisture conservation and fertilizer								
M_1	9	8	12	10	51.1	45.8	66.7	66.9
M_2	11	8	15	11	54.2	47.7	66.9	68.7
M_3	12	9	15	12	54.7	48.6	67.9	69.6
SEm±	0.5	0.3	0.6	0.5	1.20	0.63	0.62	0.71
CD (P=0.05)	NS	NS	NS	1.31	3.35	1.75	NS	1.98
Cultivar								
V_1	9	6	12	9	50.2	42.7	66.4	66.3
V_2	13	8	19	12	60.2	49.9	68.1	69.3
V_3	10	10	12	13	49.5	49.4	66.9	69.6
SEm±	0.5	0.3	0.6	0.5	1.20	0.63	0.62	0.71
CD (P=0.05)	1.26	0.9	1.7	1.3	3.4	1.8	NS	2.0
Mean of year	10.5	8.1	14.1	11.1	53.3	47.3	67.1	68.4
Pooled								
Y								
SEm±	0.24	-	0.21	-	0.64	-	1.12	-
CD (P=0.05)	0.68	-	0.59	-	1.79	-	NS	-
Y x V								
SEm±	0.64	-	0.78	-	1.48	-	1.34	-
CD (P=0.05)	NS	-	2.19	-	4.14	-	NS	-
Spanish cultivar								
Moisture conservation and fertilizer								
M_1	10	9	10	11	44.3	42.7	67.9	66.3
M_2	10	11	11	12	45.5	42.7	67.9	67.3
M_3	10	12	11	13	45.1	43.5	68.6	69.1
SEm±	0.6	0.6	0.8	0.4	1.65	0.43	0.51	0.35
CD (P=0.05)	NS	1.68	NS	1.23	NS	NS	NS	0.98
Cultivar								
V_1	9	10	10	11	44.9	40.1	68.8	65.9
V_2	10	11	11	12	44.1	43.2	67.2	67.8
V_3	9	12	11	13	45.8	45.5	0.51	68.9
SEm±	0.6	0.6	0.8	0.4	1.65	0.43	NS	0.35
CD (P=0.05)	NS	1.7	NS	1.2	NS	1.2	68.1	1.0
Mean of year	9.4	10.7	10.5	11.9	44.9	42.9		67.6
Pooled								
Y								
SEm±	0.89	-	0.71	-	0.22	-	0.14	-
CD (P=0.05)	NS	-	NS	-	0.60	-	0.39	-
Y x V								
SEm±	0.64	-	0.64	-	0.93	-	0.62	-
CD (P=0.05)	1.78	-	1.79	-	2.60	-	1.72	-

Table 2 Effect of treatments on yield and economics of groundnut

Treatment	Pod yield (kg/ha)		Haulm yield (kg/ha)		Oil yield (kg/ha)		Net returns (Rs/ha)		BCR	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Virginia cultivar										
Moisture and fertilizer										
M_1	2202	1886	2773	2539	736	601	21902	23306	3.18	3.31
M_2	2438	2088	2906	2832	822	676	24614	26519	3.35	3.53
M_3	2380	2146	3018	3005	808	785	23434	27040	3.10	3.42
SEm±	68.8	22.2	127	31.9	25.3	10.4	890	513	0.08	0.05
CD (P=0.05)	NS	62	NS	89	NS	29	NS	1432	0.24	0.14
Cultivar										
V_1	2173	1918	2816	2659	714	603	21143	23530	3.00	3.22
V_2	2828	2058	2883	2761	997	678	29140	25829	3.75	3.44
V_3	2019	2144	2997	2957	667	701	19666	27506	2.85	3.60
SEm±	68.8	22.2	127	31.9	25.3	10.4	890	513	0.08	0.05
CD (P=0.05)	192	62	NS	89	70.8	29.2	2484	1432	0.24	0.14
Mean of year	2340	2040	2899	2792	789	687	23317	25622	3.21	3.42
Pooled										
Y										
SEm±	100.3	-	72.8	-	29.1	-	2328	-	0.22	-
CD (P=0.05)	280	-	NS	-	81.3	-	NS	-	NS	-
M										
SEm±	60.4		95.2		29.7		826		0.07	
CD (P=0.05)	NS		265		NS		NS		NS	
V										
SEm±	60.4	-	95.2	-	29.7	-	826	-	0.07	-
CD (P=0.05)	168	-	NS	-	83	-	2309	-	0.22	-
Y x V										
SEm±	85.5	-	134.6	-	42.1	-	116.9	-	0.11	-
CD (P=0.05)	NS	-	NS	-	117.4	-	3263	-	0.31	-
Spanish cultivar										
Moisture conservation and fertilizer										
M_1	2307	1763	2603	2453	746	500	22823	21278	3.27	3.11
M_2	2406	1798	2636	2427	777	532	23679	21359	3.27	3.04
M_3	2409	1979	3002	2650	772	604	23752	23767	3.13	3.13
SEm±	118	26.8	142	59.8	18.5	9.25	1223	407	0.11	0.03
CD (P=0.05)	NS	75	NS	167	NS	25.82	NS	1138	NS	NS
Cultivar										
V_1	2208	1680	2599	2343	708	482	21130	19323	3.01	2.82
V_2	2528	1855	2757	2521	820	562	25284	22306	3.40	3.11
V_3	2386	2004	2884	2636	769	592	23838	24775	3.26	3.34
SEm±	118	26.8	142	59.8	18.5	9.25	1223	407	0.11	0.03
CD (P=0.05)	NS	75	NS	167	NS	25.82	NS	1138	NS	0.107
Mean of year	2374	1846	2747	2510	765	545	23418	22134	3.22	3.09
Pooled										
Y										
SEm±	180	-	212	-	90	-	2835	-	0.09	-
CD (P=0.05)	503	-	NS	-	252	-	NS	-	0.27	-
M										
SEm±	122	-	90	-	44	-	1252	-	0.12	-
CD (P=0.05)	NS	-	NS	-	NS	-	NS	-	NS	-
V										
SEm±	122	-	90	-	44	-	1252	-	0.12	-
CD (P=0.05)	NS	-	NS	-	NS	-	NS	-	NS	-
Y x V										
SEm±	145	-	127	-	50.5	-	1771	-	0.17	-
CD (P=0.05)	NS	-	NS	-	141	-	NS	-	NS	-

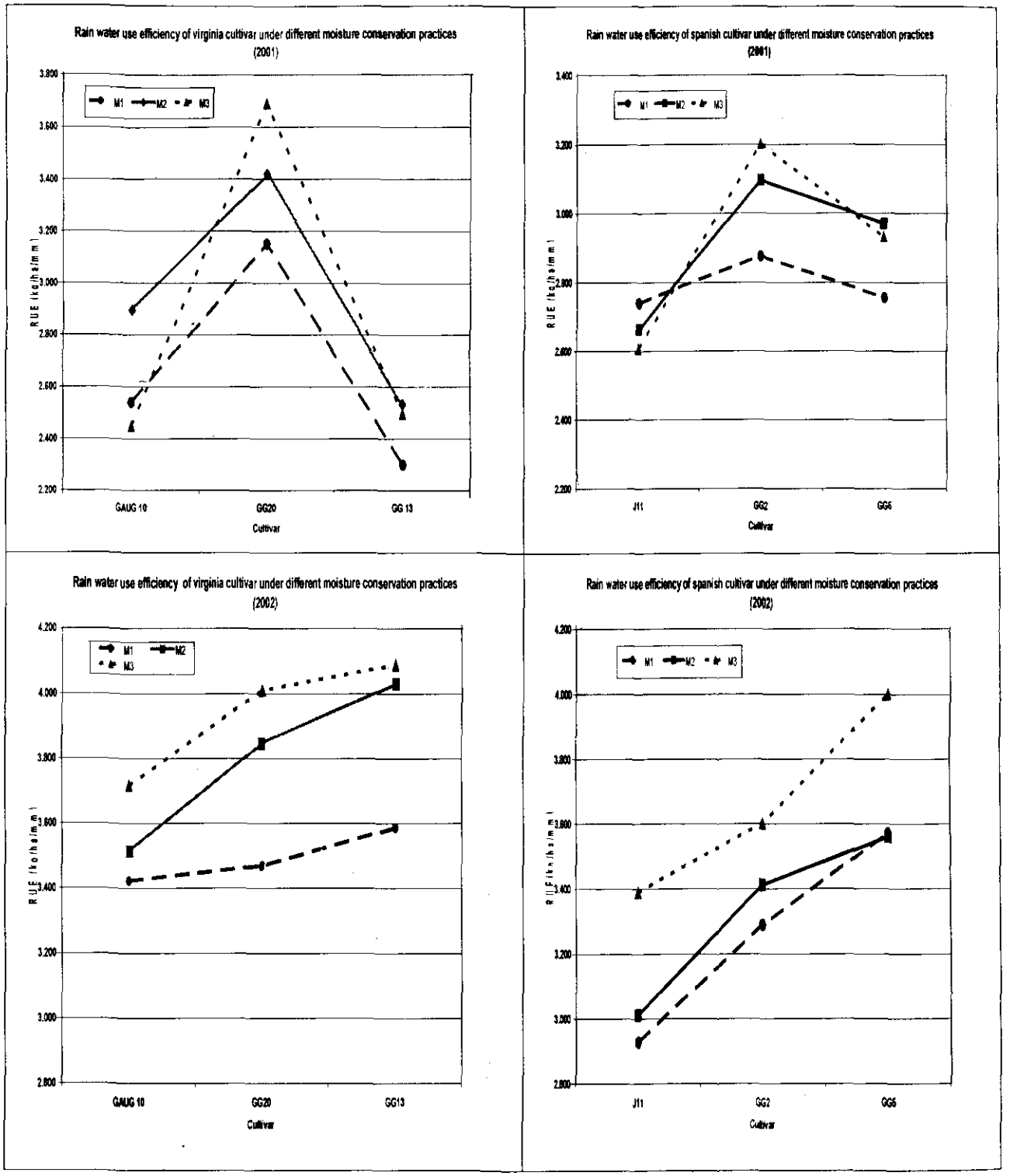

Figure 1. Rain water use efficiency as influenced by cultivar and moisture conservation practices (2001 and 2002)

In 2002, the recommended method of moisture conservation and fertilizer (M_3) adopted either in Virginia or Spanish cultivar gave higher RUE compared with the farmers practice (M_1). The lowest RUE was recorded under M_1 treatment. Among the cultivars, GG 13 of Virginia and GG 5 of Spanish gave the maximum RUE of 4.088 and 4.000 kg/ha/mm, respectively, under M_3 treatment. The lowest RUE of 3.422 and 2.928 kg/ha/mm was recorded by local cultivar, GAUG 10 (Virginia) and J 11 (Spanish), respectively under farmers method of moisture conservation and fertilizer application (M_1). More pod yield due to better availability of moisture and nutrients under M_3 resulted in better RUE compared with the farmers practice of moisture conservation and fertilizer application (M_1). Sandhya *et al.* (1994) reported higher rainfall use efficiency under improved method of moisture conservation practice compared with the control.

Economics: Net returns in Virginia and net returns and BCR in Spanish did not differ significantly in 2001 (Table 2). However, in 2002, recommended moisture conservation and fertilizers (M_3) gave significantly higher net returns of Rs. 27040/ha along with a BCR of 3.42, closely followed by M_2 (Rs. 26519/ha) but with a higher BCR (3.53), than that recorded under M_1 (Rs. 23306/ha, BCR 3.31) in Virgini cultivars. Almost similar trend was observed in Spanish cultivar also. Higher net returns under M3 suggest that the improved technology for moisture conservation is economically viable. Virginia cultivar GG 20 proved superior to remaining two cultivars and recorded the highest net returns (Rs. 29140/ha) and BCR (3.75) in 2001. However, in 2002 cultivar GG 13 gave the maximum net returns (Rs. 27506/ha) and BCR (3.60). Pooled basis, GG 20 found superior to both the cultivars and recorded maximum net returns of Rs. 27484/ha with a BCR of 3.59. Spanish cultivar differed significantly for economics in 2002 only where cultivar GG 5 gave highest net returns (Rs. 24775/ha) and BCR (3.34). The lowest net returns and BCR was recorded by J 11, a local cultivar. Since net returns is a net economic value of pod and haulm yields, higher yield of cultivars and under improved moisture conservation practices in respective years gave higher net returns. Khistria *et al.* (2003) reported higher net returns and BCR under improved method of moisture conservation than that in no moisture conservation in rainfed groundnut.

Conclusion: Virginia cultivar GG 13 and Spanish cultivar GG 5 under improved method of moisture conservation (opening of furrow after every third row) and recommended dose of fertilizer (12.5 kg N and 25 kg P_2O_5/ha) produced higher yield and gave maximum net returns under rainfed, low rain fall situations of Saurashtra region of Gujarat.

Acknowledgement: The financial support received by the National Agricultural Technology Project under Rainfed Oilseeds Production System is thankfully acknowledged.

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J. Oilseeds Res., **23**(2) : 205-208 (2006)

Direct and residual effect of Zn application in groundnut-wheat cropping system in Alfisols

Y.P. Singh and Smita Chaudhary

Krishi Vigyan Kendra, Banasthali Vidyapith (Deemed University)-304 022, **Rajasthan**

(Received: February, 2005; Revised: May, 2006; Accepted: June, 2006)

Abstract

A field experiment was conducted during 1999-2001 to study the effect of zinc on pod yield and Zn uptake in groundnut (*Arachis hypogaea* L.) and their residual effect on succeeding wheat (*Triticum aestivum* L.) using 6 soils of old alluvial plains of Tonk district of Rajasthan. Application of Zn @ 2.5 and 5.0 kg/ha produced 16.0 and 21.2% higher pod yield in groundnut crop over control. Among the soils, maximum pod yield of groundnut was recorded in sandy loam soil (1553 kg/ha) followed by loamy sand (1469 kg/ha) and sandy soil (1427 kg/ha). Zn-uptake by pods increased significantly with increasing levels of zinc and maximum value (96.7 g/ha) was recorded with application of 5.0 kg Zn/ha. Residual effect of zinc @ 2.5 and 5.0 kg/ha application increased the grain yield of wheat by 7.1 and 15.4%, respectively over control. Similar trend was found in straw yield of wheat. In the case of residual effect of Zn within soil texture, maximum grain yield was obtained in sandy loam (4520 kg/ha) followed by loamy sand (4356 kg/ha) and sandy soil (3622 kg/ha). Residual effect of Zn also increased the Zn uptake by grain and straw of wheat significantly over control. The highest Zn uptake values 112.4 g/ha by grain and 93.5 g/ha straw was obtained at their residual effect of 5.0 kg/ha application. The higher yields of groundnut-wheat are possible in Zn deficient alfisols by using 5.0 kg Zn/ha/year in groundnut crop.

Key words: Zinc, groundnut, wheat yield, residual effect, Zn uptake

Introduction

Among the micronutrients, the deficiency of Zn is the most widespread in Indian soils. The extent of Zn deficiency is about 21 and 49% in Rajasthan and India, respectively (Singh, 1999). The total geographical area in alfisols accounts to about 2.507 lakh ha in Rajasthan (Totawat and Somani, 2001). Alfisols are more severely affected by Zn deficiency (34%) compared to other micronutrients (Singh, 2000). Important causes of Zn deficiency in soil are cultivation of high yielding varieties, poor soil organic matter content, coarse texture soil, soil erosion, imbalance use of chemical fertilizer and irrigation water having carbonate and bicarbonate ions.

In irrigated areas groundnut and wheat crop rotation is widely practiced in alfisols of arid, semi-arid parts of Rajasthan but their average produce is extremely low. The sustained higher crop yield and nutritional value are possible by proper nutrient input and management practices. Therefore, the present study was undertaken to find out the effect of different zinc levels on groundnut and their residual effect on wheat under field conditions using six soils

Material and methods

Fourteen, surface soil samples (upto 15 cm) were collected randomly from irrigated field of farmers at different locations of Tonk district of Rajasthan. Out of 14 samples six soil samples denoted as A to F were found low for available zinc (<0.6 mg/kg soil) selected for the studies. Soil samples from experimental field plots were analysed for physico-chemical properties using standard methods and available zinc was extracted by DTPA (Lindsy and Norvell, 1978) and determined with the help of atomic absorption spectrophotometer. Important physico-chemical properties of the experimental fields are presented in Table 1. The area falls under Zone-III-A in semi-arid regions of arid ecosystem and soils belong to alfisol (Totawat and Somani, 2001). Three levels of zinc, 0.0 (control), 2.5 and 5.0 kg/ha were applied as zinc sulphate. The recommended doses of 20 kg N : 40 kg P_2O_5 : 40 kg S/ha was applied through urea, single super phosphate and gypsum, respectively. All the fertilizers including zinc were applied at the sowing time.

The experiment was laid out in factorial Randomized Block Design. Groundnut (var. MA-10) was sown at first rain of the season (second week of July, 1999 and first week of July 2000) in a net plot size of 10m x 20 m keeping four replications. The rainfall received during groundnut cropping period was 413 mm in first and 355 mm in second year of experimentation, respectively. After harvesting of matured crop of groundnut, the wheat crop (var. Raj-3765) was grown in the same plots for study of

the residual effect of Zn-application. The basal application of N and P_2O_5 @ 90 kg and 40 kg/ha were applied through urea and diaammonium phosphate, respectively. Full dose of P_2O_5 and half dose of N was applied at the time of sowing and remaining half was top dressed in two splits at crown root initiation and tillering stages. Wheat crop was sown in the third week of November during both the years. All the package and practices were followed as per recommendations. Zinc content in pods of groundnut, grain and straw of wheat were determined after digestion in tri-acid mixture (9:3:1 of HNO_3 : $HClO_4$: H_2SO_4) and analyzed for total zinc by atomic absorption spectrophotometer. The uptake of zinc by pods of groundnut and grain and straw of wheat crop was estimated by multiplying zinc content with corresponding yields.

Results and discussion

Effect of Zn on pod yield of groundnut: The pod yield of groundnut increased significantly with successive application of zinc @ 2.5 and 5.0 kg/ha (Table 2). The increase in pod yield of groundnut due to Zn application @ 2.5 and 5.0 kg/ha was 16.0 and 21.2% higher than control. These observations support the work of Takkar *et al.* (1975) and Khurana *et al.* (1996).

Among the soils, sandy loam soil produced significantly higher pod yield of groundnut (1553 kg/ha) followed by loamy sand (1469 kg/ha) and sandy soil (1427 kg/ha). These responses might be due to the sandy loam soil having higher initial value of available Zn as well as water holding capacity followed by loamy sand and sandy soil. Significant interaction effect of soil texture and Zn levels was observed in pod yield of groundnut. The maximum and significantly higher pod yield of groundnut was observed at 5 kg Zn/ha application in sandy loam soil, followed by loamy sand and sandy soil, respectively.

Zn uptake by pods of groundnut: Zinc uptake by pods (shell + kernel) of groundnut increased significantly with increasing levels of Zn compared to control (Table 3). Among the Zn levels, 5.0 kg/ha recorded the highest uptake (96.7 g of Zn/ha). Increasing trend of Zn uptake with increase in its application rate may be due to increase in the availability of Zn in soil thereby increasing the concentration of Zn in plant and yield of groundnut.

The Zn uptake by pods of groundnut was significantly higher in sandy loam soil (78.5 g Zn/ha), followed by loamy sand (71.0 g Zn/ha) and sandy soil (68.9 g Zn/ha). Interactions of Zn levels and soil texture indicated significantly higher Zn-uptake by pods of groundnut was observed under 5 kg Zn/ha level in sandy loam soil followed by 5 kg Zn/ha application in loamy sand and sandy soil. The higher Zn uptake by pods of groundnut in sandy loam soil may be because of higher initial value of available Zn among other soils.

Residual effect of Zn on wheat: Application of zinc to groundnut @ 2.5 and 5.0 kg Zn/ha resulted a residual effect on wheat grains with a mean increase of 7.1 and 15.4%, respectively over control. The higher grain yield of wheat (4635 kg/ha) was observed with residual effect of 5.0 kg Zn/ha application. Similarly, residual effect of Zn also increased straw yield of wheat. Residual effect of Zn application @ 2.5 and 5.0 kg/ha increased the mean straw yield of wheat by 10.5 and 18.8% over control. The residual effect of Zn improving the yield of wheat might be due to increase in available Zn status in soil after application.

Among the soils, sandy loam soil produced significantly higher grain yield of wheat (4520 kg/ha), followed by loamy sand (4356 kg/ha) and sandy soil (3622 kg/ha). Similar trend was found in straw yield of wheat. Significant interaction effect of soil texture and Zn was observed in both grain and straw yield of wheat. Higher yield of grain and straw of wheat was at residual effect of 5 kg Zn/ha application in sandy loam soil as compared to loamy sand and sandy soils.

Table 1 Physico-chemical properties of experimental fields

Location	Texture	Soil code	pH	EC (dS/m)	OC (%)	Available nutrients			
						N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (Mg/kg)
Bharutia	Loamy sand	A	8.1	0.31	0.15	111.8	7.4	195.1	0.32
Kibara	Sandy loam	B	7.9	0.26	0.23	146.5	9.3	207.8	0.43
Jugalpura	Sandy	C	8.1	0.43	0.16	102.7	6.1	187.3	0.30
Pallai	Loamy sand	D	7.9	0.32	0.16	126.2	8.1	198.6	0.46
Banasthali	Sandy loam	E	7.8	0.36	0.18	151.7	8.6	212.8	0.45
Motipura	Sandy loam	F	7.6	0.22	0.31	142.4	10.6	240.5	0.54
Mean	-	-	7.9	0.31	0.20	130.1	8.4	207.0	0.42

Table 2 Effect of zinc application on pod yield (kg/ha) and its uptake (g/ha) by pods (shell+kernel) of groundnut (2 years mean)

Soil code	Levels of zinc (kg/ha)			Mean
	0.0	2.5	5.0	
Pod yield				
A	1274	1529	1613	1472
B	1332	1589	1679	1533
C	1289	1474	1517	1427
D	1351	1526	1560	1466
E	1387	1573	1615	1525
F	1435	1619	1747	1600
Mean	1338	1552	1622	1504
Zn uptake				
A	48.9	73.3	90.2	70.8
B	52.0	74.7	100.7	75.8
C	42.8	72.7	91.5	68.9
D	51.3	71.7	90.5	71.2
E	54.1	75.5	96.9	75.5
F	60.3	82.6	110.1	84.3
Mean	51.6	75.1	96.7	74.4
CD (P=0.05) for pod yield	Soil - 0.95; Zn level - 0.70; Soil x Zn level - 1.64			
CD (P=0.05) for Zn uptake	Soil - 25; Zn level - 18; Soil x Zn level - 46			

Table 3 Residual effect of zinc application on grain and straw yield (kg/ha) and its uptake (g/ha) by grain and straw of wheat (2 years mean)

Soil code	Levels of zinc (kg/ha)			Mean
	0.0	2.5	5.0	
Pod yield				
A	4123 (4876)*	4342 (5133)	4610 (5469)	4358 (5159)
B	4142 (4946)	4496 (5354)	4816 (5732)	4471 (5245)
C	3291 (4298)	3572 (4655)	4004 (5209)	3622 (4721)
D	4089 (5061)	4361 (5402)	4613 (5663)	4354 (5042)
E	4173 (5163)	4496 (5509)	4827 (5892)	4512 (5521)
F	4273 (4059)	4522 (5306)	4939 (5768)	4578 (5374)
Mean	4015 (4732)	4298 (5227)	4635 (5622)	
Zn uptake				
A	68.2 (56.1)**	77.5 (73.9)	105.2 (89.8)	83.6 (73.3)
B	76.1 (60.4)	88.8 (79.9)	118.4 (98.8)	94.4 (79.7)
C	54.3 (45.7)	63.5 (59.9)	83.1 (78.8)	67.0 (61.5)
D	71.3 (51.4)	84.3 (81.0)	112.3 (96.1)	89.3 (76.2)
E	78.1 (65.3)	96.6 (83.9)	125.9 (100.6)	100.2 (83.3)
F	80.3 (66.8)	97.7 (81.6)	129.7 (97.1)	102.6 (81.8)
Mean	71.4 (57.6)	84.7 (76.7)	112.4 (93.5)	89.5 (75.9)
CD (P=0.05) for pod yield	Soil - 1.86 (1.22); Zn level - 1.31 (0.86); Soil x Zn level - 3.22 (2.11)			
CD (P=0.05) for Zn uptake	Soil - 82 (140); Zn level - 58 (99); Soil x Zn level - 141 (243)			

Figures in parenthesis indicate * straw yield ** Zn uptake by straw.

Zn uptake by wheat: Increasing level of residual zinc significantly increased the Zn uptake by grain and straw of wheat. The highest Zn uptake by grain (112.4 kg Zn/ha) was observed at the residual effect of 5.0 kg Zn/ha. Residual Zn enhanced utilization of Zn by grain from 71.4 g/ha in control to 112.4 g/ha at 5.0 kg Zn/ha application. Effect of residual Zn at 2.5 and 5.0 kg/ha increased mean Zn uptake by 18.6 and 32.7% over their preceding levels of Zn application. The Zn uptake by grain of wheat among the soils ranged from 67.0 g Zn/ha (sandy soil) to 99.1 g Zn/ha (loamy sand soil).

The highest Zn uptake by straw (93.5 g Zn/ha) was observed at a residual effect of 5.0 kg Zn/ha. The lowest Zn uptake was observed in control plots (57.6 g Zn/ha) and in increased significantly with increasing levels of Zn. With increasing level of Zn, its uptake by grain and straw increased mainly due to increase in crop yield and available Zn status in soil. The Zn uptake by straw of wheat among the soils ranged from 61.5 g Zn/ha in sandy soil to 79.5 g Zn/ha in sandy loam soil. The highest Zn uptake was recorded in sandy loam soil because of more availability of Zn at initial level amongst all soil textures.

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J. Oilseeds Res., 23(2) : 209-214 (2006)

Effect of tillage and preceding crops on sustainable soybean, *Glycine max* (L.) Merill production

S.D. Billore, A. Ramesh, O.P. Joshi, A.K. Vyas and N. Pandya

National Research Centre for Soybean, Indore-452 017, MP

(Received: October, 2002; Revised: February, 2006; Accepted: June, 2006)

Abstract

Field experiment were carried out for six cropping cycles to study the effect of extent of tillage and preceding crops sustainable soybean production. No-till invariably, except initial year, yielded lesser (2.6 to 35%) than conservation and conventional tillage. However conservation tillage yielded higher (up to 24%) than conventional tillage in 4 out of the 6 years. Among the preceding crops, linseed was the only crop that adversely affected the soybean yield to the tune of 15.7 and 27.8% over wheat and 3.1 and 19.7% over chickpea in no-till and conservation tillage, respectively. The interaction effect brought out that soybean yielded significantly higher under no-till and conservation till when grown after chickpea/ safflower and mustard, respectively and remained unaffected due to different tillage systems when grown after wheat. Gross and net energy out puts and net returns from soybean after wheat and mustard showed significantly higher values and were at par. In case of energy use efficiency, energy productivity and benefit cost ratio, soybean after all the preceding crops except linseed showed higher values. Stability analysis showed that soybean production was found comparatively stable in conservation tillage. All the three tillage systems behaved identically with respect to relative stability. Stability analysis revealed that the soybean succeeding chickpea and safflower followed by wheat showed stable performance over tillage systems.

Key words: Soybean, sustainability, stability, preceding crops, tillage

Introduction

Introduction

Conservation tillage is becoming increasingly popular because it involves lower costs, saves energy, and soil conditions in long run. West *et al.* (1996) reported 8% reduction in soybean yield in com - soybean rotation under no-till as compared to mould board plough till system. Performance of soybean in no-till systems depends upon soil drainage and previous crop characteristics (Guy and Oplinger, 1989), soil type, weed infestation etc. among other factors. No-till system is considered to be best suited to well-drained / soils and crop rotations compared with poorly drained and monoculture (Griffith and Wollenhaupt, 1994). The information available leaves a scope for investigating the effect of conserved tillage and earlier crop grown on the productivity of soybean on Vertisols of Central India. The information generated on this aspect through a long-term experiment is reported. The objective of the study was to investigate the effect of extent of tillage and preceding crops on the productivity of soybean.

Material and methods

A field experiment at a fixed site was conducted from 1995 to 2001 at research farm of National Research Centre for Soybean, Indore. The experimental soil belonging to Typic chromusterts had pH 7.86, EC 0.14 dS/m, organic carbon 0.30 %, available P 4.80 kg/ha and available K 280 kg/ha. The study conducted in strip plot design comprised 3 tillage treatments viz., no-till, conservation (2 cross harrowing) and conventional (deep ploughing, 2 harrowing and planking) as main plots and 5 cropping systems i.e. soybean (JS 71 05) - followed by wheat (Sujata), chickpea (JG 218), mustard (Pusa bold), safflower (JSF 1) and linseed ® 17) as sub-plots with three replications. The tillage treatments were applicable to both the crops in a system. The crops in the systems received N: P: K doses (kg/ha) of: 100:27:33 (wheat), 60:13.5:17 (mustard), 30:7:9 (linseed), 30:9:0 (safflower), 25:27:0 (chickpea) and 20:27:17 (soybean). The plot size was 3.6m x 6 m. Soybean was planted between the last week of June to first week of July during the course of experimentation depending on the onset of monsoon.

The economics of each treatment were calculated as per the prevailing prices of inputs and outputs. The energy budget of the treatments, energy intensiveness (EI) and energy productivity (EP) were worked out as per the procedure given by Fluck (1979), Burnett (1982) and Mittal and Dhawan (1988), respectively. Sustainability index, stability and relative stability were estimated as per the procedure suggested by Finley and Wilkinson (1963)

and Raun *et al.* (1993). The type of stability is decided on regression coefficient (b) and mean values. If 'b' is equal to unity, the treatment is considered to have average stability (same performance in all the environments). If 'b' is more than unity, it is suggested to have less than average stability (good performance under favorable environments) and if 'b' is less than unity, it is reported to have more than average stability (good performance under poor environment).

The total rainfall received during 2000-01 was deficit (486 mm), optimum (902-969 mm) in 1995-96, 1998-99 and 1999-00 and above normal (1167 -1332 mm) in 1996-97 and 1997-98. The average rainfall of the region is 900 mm.

Results and discussion

Effect of tillage: Growth and yield attributes of soybean remained unaltered due to different tillage systems (Table 1). Marginally higher plant height, branches/plant, pods/plant and seed yield/plant were associated with conventional tillage while, seeds/plant and seed index were numerically higher in conservation tillage. Conservation tillage exhibited superiority in seed yield of soybean (up to 24%) over conventional tillage in four out of 6 years of experimentation (data for individual years not amended). Soybean grown under no-till recorded lower yields (2.6 to 35.0 %) as compared to conservation and conventional tillage in all the years except in the first year. However, the yield reduction (21 to 35 %) was greater in unfavorable environments (with respect to quantum as well as distribution of rains) prevailing during 1996-97, 1998-99 and 2000-0 1. West *et al.* (1996) also observed lower yield of soybean under no-till compared to other tillage systems. Cumulative data (Table 2, Fig. 1) revealed that soybean productivity, irrespective of cropping systems, was same under three tillage systems. This indicates that no-till or conservation tillage systems may be as productive as conventional tillage.

Sustainable yield index (SYI) revealed that the soybean cultivation under conservation and no-till was least affected by seasonal changes as compared to conventional tillage (Table 2). In the present context of changed climatic pattern (four drought years among last five years) exhibited by Malwa plateau, the information has utility to switch over to conservation tillage which may stabilise the soybean yield levels as the information generated brings out that increased intensity of tillage increases the sensitivity to seasonal changes. The mean SYI value (0.30) for both no-till and conservation till indicated that these systems are likely to give minimum guaranteed yield of 30 % of potential, yield, in comparison to minimum possible guaranteed yield of 34 % for conventional tillage (SYI 0.34). On the basis of data generated over six years, it can be assumed that the stabilization effect has started showing up and situation may be still better in future with increase in organic carbon content and microbial dynamics in rhizosphere soil. Conservation tillage has been documented to improve the organic carbon content and biological properties of the soil (Halvarson *et al.*, 2002).

Although the differences between the stability indices (b values) among the three tillage systems are not large (0.914 to 0.941), the conservation tillage (0.914) performed better than no-till and conventional tillage systems under unfavourable yielding environment. Relative stability analysis on tillage systems encompassing cropping systems as expressed by 'b' and R^2 values (Table 3) showed that there existed non-significant variations between no-till vs. conservation tillage, no-till vs. conventional tillage and conservation vs. conventional tillage indicating all the three tillage system behaved identically in the framework of experimentation.

Energy analysis revealed that the tillage operations did not influence the gross energy output (Table 4). However, net energy out put, energy use efficiency and energy productivity differed significantly with tillage treatments. The energy input increased linearly with the extent of tillage. The maximum and the minimum values for these parameters were associated with no-till and conventional tillage. The gross and net returns and benefit cost ratio showed a decreasing trend with increasing the extent of tillage.

Effect of preceding crops: Soybean plant height remained unaffected due to preceding crops (Table 1). Significantly lowest branches, pods, seeds and seed yield/plant were noted when soybean was grown after linseed and these characters showed non-significant differences in remaining preceding crops. The maximum seed index was recorded when soybean was grown after safflower and was at par after chickpea and linseed. Averaged seed yield over six years revealed that the preceding linseed crop had deleterious effects on soybean productivity (Table 2). The decline in productivity noted was to the tune of 15.7 and 27.8% in conservation and no-till as compared to preceding wheat and the 1.13 and 19.73% to preceding chickpea, which are the major crops in soybean based cropping system in the region. The lower productivity of succeeding soybean crop to linseed can be ascribed to possible known allelopathic effect (Kirkegard *et al.*, 1997) of linseed crop residues. Soybean grown after wheat and mustard showed comparable SYI in conservation and conventional tillage systems, whereas the no-till treatment showed lower values indicating the least influence of seasonal changes under no-till. On the contrary soybean grown after linseed and safflower showed higher SYI under conventional tillage leading to variations on account of seasonal changes. However, the

wheat - soybean, and mustard - soybean; chickpea - soybean and safflower - soybean under no-till, and wheat soybean and linseed - soybean in conservation and conventional tillage behaved morel less identically.

Stability analysis (b values) revealed that the soybean succeeding chickpea and safflower followed by wheat showed stable performance over tillage systems (values close to unity). Among different tillage systems, conservation tillage resulted in better performance of all the crops as compared to no-till and conventional tillage. Among cropping systems, soybean followed by safflower or mustard performed better than remaining preceding crops in rotation under favourable environment.

Analysis of relative stability of tillage treatment pairs (Table 3), in general, revealed that although the b values for conventional vs. conservation tillage were positive indicating an edge of former over later, their magnitude was lower as compared to conservation vs. conventional and no-till vs. conservation tillage. This shows that it would be advantageous to switch over to no-till or conservation till to achieve economy in cost of cultivation.

Gross and net energy out puts and net returns from soybean after wheat and mustard were at par but significantly higher than other crops (Table 4). Energy use efficiency, energy productivity and benefit cost ratio were the highest is soybean - mustard and lowest in soybean - linseed cropping sequence.

Table 1 Soybean growth and yield attributes as influenced by preceding crops and tillage operations (pooled for six years)

Treatment	Plant height (cm)	Branches/plant	Pods/plant	Seeds/plant	Seed yield/plant (g)	Seed index
Tillage						
No till	39.7	4.0	40	79	8.9	10.2
Conservation tillage	40.5	4.0	42	81	9.0	10.4
Conventional tillage	43.2	4.0	44	80	9.4	10.0
SEm±	1.3	0.2	2.8	1.4	1.0	1.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Soybean after preceding crop						
Soybean - Wheat	40.6	4.0	42	65	9.0	9.9
Soybean - Chickpea	38.0	4.0	40	67	8.0	10.8
Soybean - Safflower	39.3	4.0	36	64	8.0	11.0
Soybean - Linseed	38.8	4.0	26	61	7.0	10.4
Soybean - Mustard	39.6	4.0	41	82	9.0	9.8
SEm±	1.2	0.1	2.4	0.4	0.4	0.4
CD (P=0.05)	NS	NS	6.6	1.1	1.3	1.0

Table 2 Soybean yield (kg/ha), sustainable yield index and stability as influenced by preceding crops and tillage operations (pooled for six years)

Treatment	Tillage											
	No till			Conservation			Conventional			Mean		
	Yield	SYI	b	Yield	SYI	b	Yield	SYI	b	Yield	SYI	b
Soybean-wheat	1239	0.29	0.997	1217	0.33	0.705	1195	0.30	0.974	1195	0.31	0.892
Soybean-chickpea	1153	0.23	1.100	1085	0.28	0.925	1126	0.28	1.096	1126	0.26	1.040
Soybean-safflower	1217	0.25	1.145	1113	0.25	0.960	1156	0.29	1.045	1137	0.26	1.050
Soybean-linseed	963	0.23	0.723	1052	0.30	0.817	1052	0.33	0.918	1053	0.29	0.819
Soybean-mustard	1141	0.36	1.051	1266	0.44	1.595	1214	0.43	1.098	1214	0.41	1.248
Mean	1137	0.30	0.940	1140	0.30	0.914	1143	0.34	0.941			

Significance levels for yield

	SEm±	CD (P=0.05)
Tillage (T)	68.9	NS
Preceding crops (PC)	10.7	30.0
T x PC	18.6	51.9

Table 3 Relative stability of soybean as influenced by tillage systems and preceding crops

Treatment pair	b	R^2	Treatment pair	b	R^2
Tillage Systems			**Soybean - Linseed**		
No till v/s conservation tillage	0.306	0.169	No till v/s conservation tillage	0.106	0.302
No till v/s conventional tillage	0.312	0.487	No till v/s conventional tillage	0.047	0.017
Conservation v/s conventional tillage	0.032	0.005	Conservation v/s conventional tillage	-0.062	0.025
Soybean-Wheat			**Soybean-mustard**		
No till v/s conservation tillage	0.184	0.120	No till v/s conservation tillage	0.060	0.042
No till v/s conventional tillage	0.252	0.207	No till v/s conventional tillage	0.105	0.052
Conservation v/s conventional tillage	0.065	0.070	Conservation v/s conventional tillage	0.042	0.035
Soybean-chickpea			**Soybean-safflower**		
No till v/s conservation tillage	0.309	0.493	No till v/s conservation tillage	0.175	0.361
No till v/s conventional tillage	0.214	0.610	No till v/s conventional tillage	0.390	0.544
Conservation v/s conventional tillage	-0.092	0.083	Conservation v/s conventional tillage	0.210	0.660

Table 4 Effect of tillage and preceding crops on energy budgeting and economics of soybean

Treatment	Energy input (MJ/ha)	Gross energy output (MJ/ha)	Net energy output (MJ/ha)	Energy use efficiency	Energy productivity (g/MJ)	Net returns (Rs/ha)	B:C ratio
Tillage							
No till	6895	16714	9819	2.42	164	6120	2.17
Conservation tillage	8247	16758	8511	2.03	138	5900	2.07
Conventional tillage	10865	16802	5937	1.55	105	5430	1.91
SEm±	-	122.00	211.14	0.042	2.88	88.92	0.019
CD (P=0.05)	-	NS	598.37	0.118	7.96	252.01	0.055
Soybean after preceding crop							
Soybean-wheat	8669	17567	8898	2.03	138	6367	2.14
Soybean-chickpea	8669	16552	7883	1.91	130	5677	2.02
Soybean-safflower	8669	16993	8324	1.96	133	5977	2.07
Soybean-linseed	8669	15464	6795	1.78	121	4937	1.88
Soybean-mustard	8669	17846	9177	2.06	140	6557	2.17
SEm±	-	157.57	272.58	0.054	3.63	114.80	0.025
CD (P=0.05)	-	441.04	763.24	0.150	10.16	321.45	0.070

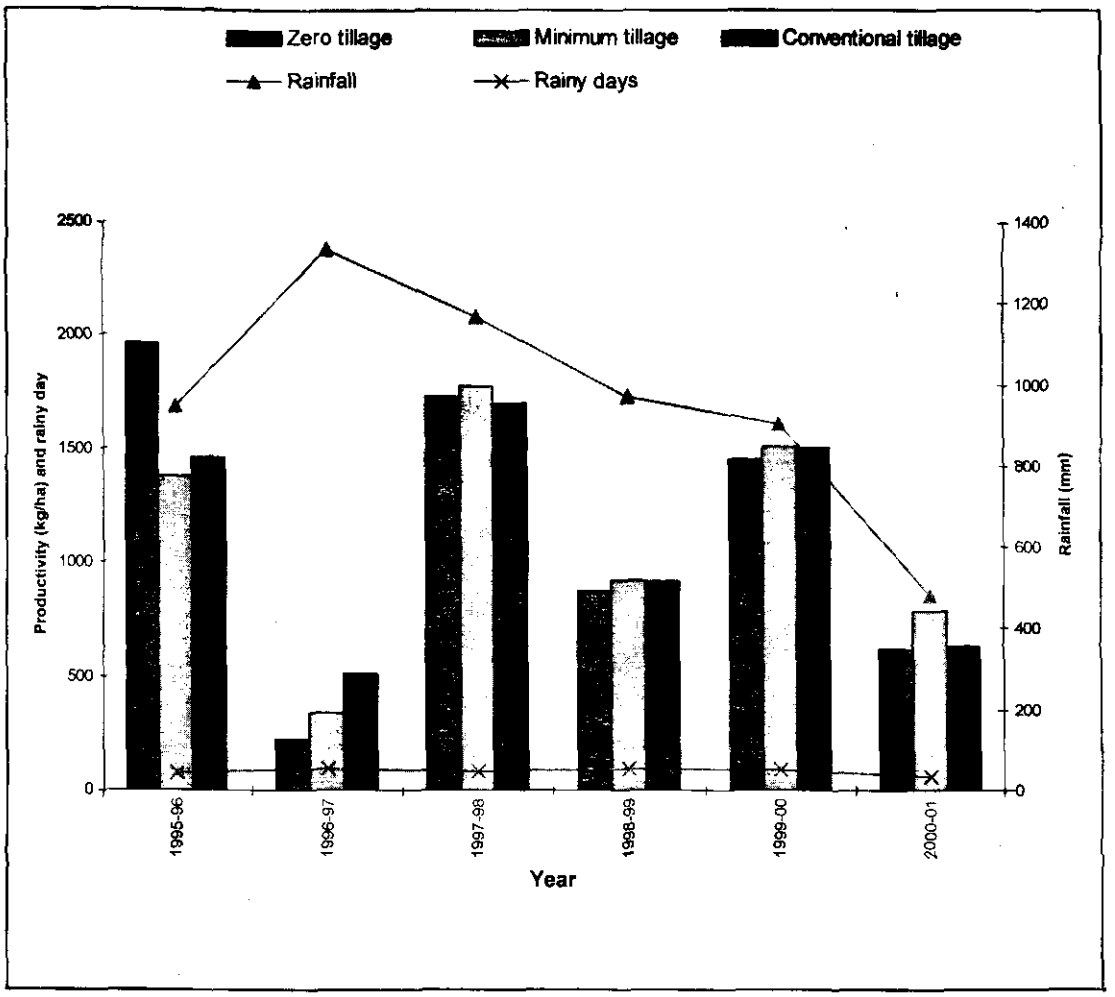

Fig. 1 Productivity of soybean under various tillage systems over six years

Interaction effect: Interaction effect of tillage and preceding crops revealed that soybean yielded significantly higher under no-till than conservation tillage and remained at par with conventional tillage when grown after chickpea and safflower (Table 2). While, soybean grown after wheat remained unaffected due to different tillage systems. Soybean grown after linseed, did performed well under conservation and conventional tillage and significantly higher than no-till. Soybean after mustard gave significantly more yield under conservation tillage followed by conventional and no-till.

SYI indicated that soybean grown after wheat sustained the productivity under conservation tillage, while soybean after safflower and linseed under conventional tillage. Soybean after chickpea and mustard sustained the productivity under conservation as well as conventional tillage. Similarly, soybean productivity was found stable under no till when grown after wheat and mustard; after chickpea in conservation tillage and after linseed in conventional tillage. Soybean performance was found stable in conservation and conventional tillage after safflower. Soybean grown after wheat and linseed did well under unfavourable environments under all three tillage systems and just reverse was true when grown after mustard. Soybean grown after chickpea and safflower performed very well under favourable environments in no-till and conventional tillage, however in conservation tillage soybean did well under unfavourable environments.

The major cropping system in the soybean command area of Central India is soybean-wheat (under irrigated regime) and soybean-chick pea (under rainfed regime) and normally grown in conventional till. Over extended period soybean grown after wheat or chickpea or other crops except linseed performed equal or better under conservation till even under unfavourable environments. Hence, it is possible to reduce the cost of cultivation by adoption of conservation tillage and obtain sustainable yields irrespective of aberrant weather conditions.

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J. Oilseeds Res., 23(2) : 215-218 (2006)

Effect of integrated plant nutrient supply *vis-a-vis* chemical fertilizers in soybean-safflower sequence on soil organic carbon, soil phosphorus fractions and available P pool

A.S. Dhawan, A.S. Karle, M.S. Deshmukh and B.B. Shendge

Department of Agricultural Chemistry & Soil Science, Marathwada Agricultural University, Parbhani-431 402, MS

(Received: July, 2005; Revised: October, 2005; Accepted: April, 2006)

Abstract

Investigations were carried out during the year 2002-2003 as a super imposed study on long term experiment under All India Co-ordinated Research Project on Oilseeds at the Department of Agronomy MAU, Parbhani. Although the major objective of the long term project is to optimize phosphorus (P) management in soybean-safflower system it was also aimed to study soil organic carbon as an index of soil health, distribution of P fractions in soil, their relative contribution to available P pool as cumulative and residual effect of IPNS *vis-a-vis* chemical fertilizer use at fixed site. The organic carbon level of soil was found to be highest and significantly superior in treatment receiving FYM @ 5 t/ha with or without PSB and 100% recommended P through chemical fertilizer in soybean-safflower cropping sequence. On the contrary the available P was found to be highest and significantly superior in treatment receiving 100% recommended P through chemical fertilizer and preceding crop was fertilized with FYM + PSB. This was also resulted into significant built up of all the P fractions over other treatments. On the basis of multiple regression equations it is revealed that the Sal- P, Al- P Fe-P, Occl- P and Organic-P are the important contributor to available P pool after soybean crop. Where as after harvest of safflower crop Sal- P, Fe-P Occl-P and RS-P were found an important contributor to available P pool.

Key words: IPNS, Vertisol, P fractions, available P pool

Introduction

In recent years there has been renewed emphasis on integrated use of fertilizers and organic manures particularly in a cropping system taking into account residual and cumulative effect of manurial practices. As it helps not only to restore and sustain soil fertility and crop productivity but also brings an economy and efficiency in fertilizer use and favourably influence the physico-chemical and biological properties of soil.

In an effort to optimize phosphorus management in soybean - safflower cropping system through integrated plant nutrient supply (IPNS) under long term experiment at fixed site it has indicated that the yields levels of component crop at fifth cycle are equally good in case of nutrient management treatment where FYM alone or in combination with PSB was applied to one of the crops and application of 100 % P through chemical fertilizers to another crop in sequence rather than supplying both the crops with 100% RDF through chemical fertilizers (Shendge, 2004). Thus application of 100% RDF through chemical fertilizers can be skipped to one of the component crops in sequence and supplied with FYM alone or in combination with PSB without sacrificing yield levels. However, merit of the nutrient management treatment for a crop or cropping system can not be judged on the basis of yield levels alone but its influence on soil organic carbon and available nutrient status of soil after harvest of crop should also be taken in to account. This forms the basis of yield sustainability in subsequent cropping cycles.

There are number of evidences in the literature signifying the importance of integrated approach of phosphors management in improving and sustaining the yield of single crop or cropping system over a period of time besides its positive effect on soil nutrient balance (Bhatnagar *et al.*, 1996; Babulkar *et al.* 2000; Balpande, 2000; Sharma and Vyas 2002).

In an effort to optimize phosphorus management in soybean - safflower cropping system through IPNS at fixed site experiment an investigation was carried out to study the effect of optimization of P management in soybean-safflower cropping sequence through IPNS on post harvest soil organic carbon levels, available P status as well as distribution and contribution of different P fractions towards available P pools in soil.

Material and methods

The present investigation was a superimposed study during the year 2002-2003 and was fifth cycle on long term experiment under All India Co-ordinated Research Project on Oilseeds being carried out at Department of Agronomy, Marathwada Agricultural University, Parbhani at fixed site since 1997-98. The experimental field was medium deep black soil (Typic haplustert) with pH 8.22, EC 0.36 dS/m organic carbon 6.5 g/kg, available N , P and K 176, 12.8 and 247 kg, respectively.

The design of experiment was Randomized Block Design with four replications. The recommended dose of fertilizer for soybean (*kharif*) was 30:60:30 and for safflower (*rabi*) was 60:40:0 NPK kg/ha, respectively. The soybean var. JS- 335 and safflower var. Sharada was used as test crops. The nitrogen was applied through urea and phosphorus through di-ammonium phosphate. The PSB culture was used through seed dressings as per the treatments.

Plot wise soil samples were collected after harvest of each crop in sequence and were analysed for soil organic carbon, soil P fractions (Peterson and Corey, 1966) and available P.

Results and discussion

Organic carbon content in the soil, after harvest of soybean was found to be highest and significantly superior in treatment T_8 where FYM + PSB was added to soybean and 100% phosphorus was applied through chemical fertilizer to preceding safflower crop in sequence (Table 1). Similarly after harvest of safflower the organic carbon status of soil was found to be highest and significantly superior in treatments where FYM + PSB and FYM alone was applied to safflower and 100% phosphorus through chemical fertilizer was applied to preceding soybean crop. The significantly higher organic carbon status under these treatments could be attributed to FYM application being a source of organic carbon itself. Moreover application of 100% P through chemical fertilizer to preceding crop in sequence might have resulted into higher production of biomass both above ground and below ground which might have contributed to higher level of soil organic carbon. Similar observations were recorded by Subramanim and Kumaraswamy (1989) where application of FYM in conjunction with chemical fertilizer has resulted into significantly higher level of soil organic carbon.

Highest available P after harvest of soybean was found in treatment where 100 % P was applied through chemical fertilizer and preceding crop in sequence was fertilized with FYM + PSB. Similarly, post-harvest soil test for available phosphorus for safflower the treatment T8 has given significantly superior values over other where 100 % recommended phosphorus was applied through chemical fertilizer and preceding crop was fertilized with FYM + PSB. This could be attributed to mutually beneficial role of chemical fertilizer and organic manure coupled with PSB culture in keeping the available P status at higher level. Babulkar *et al.* (2000) have also reported the complimentary role of organic and chemical fertilizer on improving fertility status of vertisol.

The data pertaining to relative distribution of P fractions after harvest of soybean as well as safflower crop as influenced by residual and cumulative effect of a set of nutrient management treatments indicate that the saloid -P which is loosely bound P, forms a very small fraction of total P and is easily available to plant. The mean values of different P fractions across the treatments indicate that organic P and calcium P forms the major P fractions. Where as Al-P, Fe-P and RS-P form next to those of Ca-P and organic P (Table 2 and 3).

Table 1 **Effect of phosphorus management treatments on available post-harvest soil organic carbon (%) and available P (kg/ha) in soybean-safflower cropping sequence**

Treatment for soybean	Soil organic carbon (%) after soybean	Available P after soybean	Treatment for safflower	Soil organic carbon after safflower	Available P after safflower
T_1 :No P	0.6	17.9	T_1 : No P	0.7	16.6
T_2 :100% RDP	0.6	29.0	T_2 : 100% RDP	0.7	26.0
T_3 :50% RDP	0.7	22.1	T_3 : 100% RDP	0.7	23.9
T_4 :50% RDP	0.7	22.9	T_4 : 50% RDP	0.7	18.8
T_5 :50%RDP+PSB	0.7	26.9	T_5 :50%RDP+PSB	0.8	23.9
T_6 :No P	0.6	18.2	T_6 : 100% RDP	0.7	24.8
T_7 :FYM	0.8	21.1	T_7 : 100% RDP	0.8	26.4
T_8 :FYM+PSB	0.9	25.2	T_8 : 100% RDP	0.7	28.1
T_9 :100% RDP	0.7	27.9	T_9 : 50% RDP	0.8	21.1
T_{10} : 100% RDP	0.7	28.5	T_{10} : No P	0.7	15.8
T_{11} : 100% RDP	0.7	28.6	T_{11} : FYM	0.8	25.2
T_{12} : 100% RDP	0.6	29.2	T_{12} : FYM+PSB	0.8	26.3
SEm±	0.01	0.16	SEm±	0.01	0.25
CD (P=0.05)	0.03	0.46	CD (P=0.05)	0.04	0.69

RDP = Recommended dose of P

Table 2 Effect of different phosphorus treatments on P fractions after harvest of soybean (mg/ha)

Treatment	*Sal-P*	*Al-P*	*Fe-P*	Occl-P	RS-P	Ca-P	Org.-P	Total P
T_1 : No P	8.1	26.4	34.4	7.3	40.2	127.9	193.1	437.4
T_2 : 100% RDP	10.5	34.4	43.1	11.0	48.9	274.0	261.3	684.0
T_3 : 50% RDP	9.2	32.0	38.4	9.3	45.0	195.6	228.5	558.1
T_4 : 50% RDP	9.3	31.8	39.0	9.2	45.1	198.2	223.3	545.9
T_5 : 50% RDP+PSB	9.8	33.0	41.9	9.9	46.5	215.7	231.1	587.9
T_6 : No P	8.2	27.1	35.5	7.4	40.4	130.8	191.8	438.8
T_7 : FYM	8.6	37.5	45.5	8.3	42.5	152.87	198.0	493.8
T_8 : FYM+PSB	8.9	36.0	44.2	8.7	43.2	168.4	219.0	529.4
T_9 : 100% RDP	10.2	36.9	43.8	10.7	49.9	276.1	262.4	690.0
T_{10} : 100% RDP	10.0	37.0	42.4	10.9	50.0	275.3	258.2	683.8
T_{11} : 100% RDP	10.3	35.8	46.1	10.8	49.9	282.5	264.3	696.7
T_{12} : 100% RDP	10.2	34.9	44.1	11.0	50.1	284.7	268.7	703.8
SEm±	0.0	0.69	0.93	0.11	0.27	3.67	1.58	8.89
CD (P=0.05)	0.13	1.92	2.57	0.32	0.76	10.18	4.28	24.60

*RDP = Recommended dose of P

Table 3 Effect of different phosphorus treatments on P fractions after harvest of safflower (mg/kg)

Treatment	Sal-P	Al-P	Fe-P	Occl-P	RS-P	Ca-P	Org.-P	Total P
T_1 : No P	8.1	23.9	30.0	7.0	35.4	120.7	202.9	556.1
T_2 : 100% RDP	10.2	31.4	45.2	10.0	40.8	264.5	268.5	670.6
T_3 : 50% RDP	10.3	30.4	43.8	9.8	38.1	261.9	263.7	659.0
T_4 : 50% RDP	9.3	28.4	35.6	8.1	38.1	199.4	223.0	541.9
T_5 : 50% RDP+PSB	9.8	29.8	39.2	9.1	40.2	210.3	226.2	564.7
T_6 : No P	10.3	31.8	39.1	9.7	40.9	255.6	258.8	646.3
T_7 : FYM	10.4	32.4	43.6	9.7	41.5	257.2	261.1	655.9
T_8 : FYM+PSB	10.5	33.0	44.1	8.6	42.0	259.4	265.2	663.0
T_9 : 100% RDP	10.4	34.1	43.9	9.9	41.6	266.3	270.1	676.6
T_{10} : 100% RDP	8.8	24.1	32.2	7.2	36.2	126.7	204.0	437.9
T_{11} : 100% RDP	8.6	29.9	45.2	8.0	37.0	162.4	212.1	503.2
T_{12} : 100% RDP	8.9	31.1	44.5	8.2	38.1	175.8	218.2	525.0
SEm±	0.03	0.77	0.5	0.14	0.4	3.6	1.59	36.12
CD (P=0.05)	0.08	2.13	1.5	0.39	1.1	10.0	4.42	100.0

The predominance of calcium P fractions is obvious since soils were calcareous in nature and calcium being dominant cation in the soil environment is bound to precipitate as Ca-P. The predominance of Ca- P in calcareous soil has also been reported by Kolambe (1991).

As far as phosphorus distribution into different P fractions as influenced by different P management is concerned all the P fractions are significantly higher in case of those treatments where 100 % recommended dose of P is applied either through chemical fertilizers to both the crop in sequence or through FYM with or without PSB is applied to one of the crops in the sequence.

This indicated that use of 100 % recommended dose of P through chemical fertilizer to one of the crop in sequence and FYM with or without PSB to other crop goes a long way in the built up of different P fractions. This improved level of P fraction ultimately forms the available P pools to sustain fertility of soil with respect to available P supply in long run.

The contribution of different P fractions to available pool could be very well predicted with multiple regression equations as given below.

After soybean crop

1) Available P (Olsen's) - 19.795 + 1.1832 Sal-P
- 0.0798 (Al-P) + 0.2947 (Fe -P)

(After Soybean harvest) + 3.328 (Occl- P) - 0.5162 (RS-P)
0.0576 Ca- P + 0.1219 (Org-P)
(R^2 = 0.975**)

2) Available P (Olsen's)
(After safflower harvest) - 62.815 + 10.2119 (Sal- P)
- 0.3826 (Al-P) + 0.7267 (Fe- P)
- + 2.585 (Occl-P) + 0.2938 (RS-P)
- 0.1523(Ca-P) - 0.1312 (Org-P)
- (R^2 = 0.901)**

Since all these fractions are in dynamic equilibrium with each other and also constitute the available P pool the multiple regression equation between available P as dependent variable reflects on the contribution of these fractions towards available P in presence of other fractions.

From the multiple regression equations for available P pool and different P fractions after harvest of both the crops in sequence it is revealed that Sal - P has positive contribution towards available P as it is loosely bound P fraction and is immediately available. Besides this fraction the Fe - P and Occl- P has also contributed positively towards available P as extractable- P by Olsen's reagent. However the negative partial correlation co-efficient for Ca-P in soil indicates that the extracted P by Olsen's reagent might have been reprecipitated as Ca-P as the calcium is the dominant cation in the experimental soil.

However, P distribution in soil associated with different P fractions is always in dynamic equilibrium among the different P pool characterized by dissolution precipitation reactions under the influence of different factors like pH, organic matter, ionic environment of soil etc. In long run these P fractions are bound to contribute towards available P pool when properly manipulated by application of organic matter in the form of FYM. Use of PSB may further keep in enhancing the dissolution rates. Similar observations were recorded by many workers (Verma *et al.*, 1991; Rokima and Prasad, 1991).

Acknowledgement: Authors would like to sincerely thank Dr. D. M. Hegde, Project Director, Directorate of Oilseeds Research Rajendranagar, Hyderabad for permitting to undertake super-imposed studies on the ongoing long term experiment under AICRP on Oilseeds to post graduate student of the Department of Agril. Chemistry and Soil Science and Shri. Sunil K. Thakur for typing the manuscript.

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J. Oilseeds Res., **23**(2) : 219-221 (2006)

Effect of mulching and sulphur on growth and yield of mustard, *Brassica juncea* (L.) Czern & Cosson under varying levels of irrigation

R.D. Yadav, R.G. Pareek and R.L. Yadav

Department of Agronomy, S.K.N. College of Agriculture, Jobner-303 329, Rajasthan

(Received: December, 2005; Revised: April, 2006; Accepted: June, 2006)

Abstract

A field experiment was conducted at Jobner (Rajasthan) during 2001-02 and 2002-03 with Indian mustard, [*Brassica juncea* (L.) Czern and Cosson] using 3 levels of irrigation (I_1-at flowering, I_2-at flowering and pod filling and I_3-at branching, flowering and pod filing) and four mulching treatments (control, *Saccharum munja* @ 5 t/ha, *Tephorsia purpurea* @ 5 t/ha and black polythene) in main plot and three sulphur levels (20, 40 and 60 kg S/ha) in sub-plots in Spit Slot Design on loamy sand soil. Successive increase in number of irrigations (I_1 to I_3) and levels of sulphur (20 to 60 kg S/ha) significantly increased growth parameters, yield attributes, seed, stover and biological yields and net return over their preceding levels. The black polythene mulch significantly increased the growth parameters, yield attributes, seed, stover and biological yield of *B. juncea* over *Saccharum, Tephrosia* and no mulching.

Key words: Mustard, irrigation, sulphur, mulching

Introduction

The lower productivity of mustard crop in semi arid region of India is due to limited availability of moisture at critical stages of crop growth and poor nourishment. The moisture stored in the rhizosphere of soil in areas of scanty rainfall determines the crop growth. If the limited available irrigation water and the profile stored soil moisture can be properly exploited by judicious management practices good yields can be expected. For efficient utilization of soil moisture under semi-arid condition mulching plays significant role in increasing the productivity of crops by economizing the use of irrigation or rain water and boosting nutrient use efficiency (Mahey *et al.*, 1986). Sulphur fertilization to mustard showed its role in promoting seed yield and other ancillary characters (Goswami, 1988). Hence an experiment was conducted to find out the effect of mulching and sulphur on growth and yield of mustard.

Material and methods

The field experiment was conducted during *rabi* seasons of 2001-02 and 2002-03 under semi-arid climatic conditions at Jobner (Rajasthan) in Split Plot Design with 36 treatment combinations replicated thrice with irrigation and mulching in main plot and sulphur levels in sub-plots on loamy sand soil having organic carbon 0.21 %, available nitrogen (N) 129.2 kg/ha, available phosphorus (P_2O_5) 17.5 kg/ha, available potash (K_2O) 149.5 kg/ha available sulphur 8 ppm, pH 8.3 and EC dS/m 1.30.

Treatments combinations were replicated thrice comprising three levels of irrigation (I_1-at flowering, I_2- at flowering and pod filling and I_3-at branching, flowering and pod filling) with four mulching treatments [control, *Saccharum munja* @ 5 t/ha (dried), *Tephrosia purpurea* @ 5 t/ha (dried) and black polythene (0.05 mm thick)] in main plots and three sulphur levels (20, 40 and 60 kg S/ha) in sub plots. Sulphur was applied through gypsum one day prior to sowing and incorporated in the soil and mustard cultivars Bio-902 (Pusa Jai Kisan) was sown on 28 and 29th October during the year 2001-02 and 2002-03, respectively. The crop was sown in the rows at 30 cm apart. Mulches were applied after plant emergence (10 days after sowing). Depth of irrigation water was 5 cm. Observations were recorded on growth parameters *viz.*, plant height (cm.), number of primary branches/plant, number of secondary branches/plant, drymatter accumulation/row length (g) at periodically stages and yield parameters *viz.* number of siliquae/plant, number of seeds/siliqua, test weight(g), seed yield (kg/ha), stover yield (kg/ha), biological yield (kg/ha), harvest index (%) and net return (Rs/ha) at harvest stage. The crop was harvested on 16.03.02 and 18.03.03 during first and second year, respectively.

Results and discussion

Effect of irrigation: Plant height, primary and secondary branches/plant and dry matter accumulation/meter row length increased significantly due to successive increase in number of irrigation from one to three at different phenological stages (Table 1). It is well known that where enough soil moisture for progressive plant growth is maintained either by providing irrigation or rainfall, it intends to better development of photosynthetic areas and results in an accelerate photosynthetic rate, thus, as a consequence plant growth accelerated and led to a better

accumulation of drymatter. These results are in conformity with the findings of Samui *et al.* (1986).

Application of three irrigations at branching, flowering and pod filling stages significantly improved the number of siliquae/plant, number of seeds/siliqua, seed, stover and biological yields and net return but test weight and harvest index were significantly higher upto two irrigations (Table 2). This might be due to higher photosynthesis and translocation of photosynthtes towards reproduction structures due to adequacy of soil moisture in the rhizhosphere of mustard crop. Ghatak *et al.* (1992) and Patel (1999) also reported similar results in Indian mustard.

Effect of mulching: Plant height, drymatter accumulation/meter row length, number of primary and secondary branches/plant, significantly improved due to diverse mulching treatments over control (Table 1). Further, the black polythene mulch caused a significant increase in these growth components over *Tephrosia* and *Sacchurum* mulches also. It is obvious that mulching leads to better plant growth by changing the micro climate by conserving more moisture through reducing evaporation, modifying soil temperature, controlling weeds, thus, economizing the use of irrigation water. Moreover, adequate presence of moisture to plants, results in full cell turgidity and eventually higher meristematic activity, leading to more foliage development, greater photosynthetic rate and consequently better plant growth. These results are in accordance with findings of Sachan *et al.* (1997).

The notable improvement in yield attributes (number of siliqae/plant, number of seeds/siliqua and test weight) and seed, stover and biological yields and harvest index was obtained due to mulching practices over control (Table 2). Significantly higher values of yield attributes and yield were registered under black polythene mulch followed by *Tephrosia* and *Saccharum* mulches. The minimum net return (Rs 7540/ha) was recorded under polythene mulch while maximum under Tephrosia mulch (Rs 11912/ha). The improvement in yield attributes under mulching practices could be ascribed to better availability of moisture and moderation of hydrothermal temperature which led to greater uptake of nutrients. These results are in consonance with the findings of Singh *et al.* (1996) and Gosh and Moitra (1997).

Table 1 Effect of irrigation, mulching and sulphur on growth parameters of mustard (Pooled 2001-02 and 2002-03)

Treatment	Plant height (cm)				Primary branches/ plant				Secondary branches/plant			Drymatter accumulation/row length			
	45 DAS	75 DAS	105 DAS	At harvest	45 DAS	75 DAS	105 DAS	At harvest	75 DAS	105 DAS	At harvest	45 DAS	75 DAS	105 DAS	At harvest
Irrigation															
I_1-at F	18.7	105.1	140.1	146.0	3.05	6.00	6.72	6.85	9.22	11.5	12.5	12.0	133.0	181.0	197.8
I_2-at F + PF	18.7	109.0	154.6	160.1	3.12	5.79	7.33	7.51	9.22	12.4	13.4	12.0	133.2	190.4	210.3
I_3-at B + F + PF	21.7	121.1	168.0	173.9	4.04	6.71	7.92	8.08	9.94	13.1	14.1	13.7	145.5	199.0	221.3
SEm±	0.27	1.11	1.60	1.81	0.05	0.09	0.11	0.10	0.07	0.10	0.10	0.20	1.45	1.50	1.99
CD (P = 0.05)	0.78	3.17	5.48	5.17	0.15	0.25	0.29	0.28	0.20	0.28	0.28	0.56	4.15	4.29	5.69
Mulching															
Control	18.5	105.5	141.6	146.4	2.80	5.24	6.76	6.93	8.96	11.5	12.5	11.0	130.4	182.1	198.5
S. munja (5 t/ha)	19.8	111.6	153.8	158.7	3.56	6.12	7.35	7.50	9.52	12.3	13.3	12.8	137.4	189.8	209.1
T. purpurea (5 t/ ha)	19.9	112.1	155.6	161.5	3.55	6.22	7.33	7.50	9.50	12.4	13.4	12.9	137.4	190.6	211.2
Black polythene	20.5	117.7	166.0	173.4	3.69	6.68	7.83	7.99	9.87	12.9	14.0	13.4	144.3	198.1	220.3
SEm±	0.32	1.28	1.85	2.09	0.06	0.10	0.12	0.11	0.08	0.11	0.11	0.23	1.68	1.73	2.30
CD (P = 0.05)	0.90	3.66	5.29	5.97	0.17	0.29	0.34	0.32	0.24	0.32	0.32	0.65	4.80	4.95	6.57
Sulphur (kg /ha)															
20	19.1	106.8	142.0	146.8	3.01	5.75	6.83	6.99	8.97	11.6	12.6	12.2	132.7	182.2	199.1
40	19.6	112.1	155.1	160.8	3.55	6.18	7.36	7.50	9.50	12.4	13.4	12.6	137.4	190.5	210.6
60	20.3	116.3	165.6	172.4	3.66	6.57	7.78	7.96	9.92	13.0	14.0	13.0	142.1	197.8	219. 7
SEm±	0.25	0.87	1.55	1.55	0.04	0.06	0.08	0.09	0.06	0.08	0.08	0.17	1.10	1.41	1.66
CD (P = 0.05)	0.70	2.43	4.36	4.35	0.12	0.17	0.23	0.24	0.18	0.23	0.23	0.47	3.07	3.95	4.65

B=Branching; F = Flowering; PF = Pod Filling; DAS = Days after sowing

Table 2 Effect of irrigation, mulching and sulphur on yield attributes, yield and net return of mustard (Pooled 2001-02 and 2002-03)

Treatment	*Siliquae/* plant	*Seeds/* siliqua	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Net return (Rs/ha)
Irrigation								
I_1-at F	151.8	11.2	3.36	1090	3000	4090	26.6	5372
I_2-at F + PF	195.1	12.3	3.67	1500	3870	5370	27.8	10767
I_3-at B + F + PF	232.6	12.9	3.76	1710	4260	5940	28.6	13242
SEm±	1.98	0.13	0.04	16	36	41	0.36	173
CD (P = 0.05)	5.66	0.38	0.10	46	101	116	1.03	496
Mulching								
Control	155.1	11.3	3.37	1160	3170	4300	26.9	8807
S. munja (5 t/ha)	193.0	12.1	3.64	1440	3730	5160	27.6	10915
T. purpurea (5 t/ha)	195.4	12.2	3.69	1490	3810	5290	27.8	11912
Black polythene	229.0	12.9	3.68	1650	4130	5770	28.3	7540
SEm±	2.29	0.15	0.04	19	41	47	0.42	200
CD (P = 0.05)	6.54	0.44	0.12	53	118	134	1.19	572
Sulphur (kg/ha)								
20	156.7	11.4	3.41	120	3280	4470	26.7	6629
40	194.8	12.2	3.63	1450	3750	5190	27.7	10038
60	228.0	12.8	3.76	1650	4100	5740	28.5	12714
SEm±	1.91	0.12	0.03	13	25	30	0.32	139
CD (P = 0.05)	5.36	0.33	0.08	B-	71	85	0.91	391

B = Branching; F = Flowering; PF = Pod filling

Effect of sulphur: Successive increase of sulphur doses form 20 to 60 kg S/ha reflected a significant improvement in plant height, primary and secondary branches/plant, dry matter accumulation/meter row length (Table 2). The increased uptake of nutrients due to sulphur in general and their activation at cellular level by promoting greater photosynthetic and meristamatic activity seemed to have stimulated vegetative growth of mustard (Singh *et al.*, 1990). The number of siliquae/plant, seeds/siliqua, test weight, seed yield, stover yield, biological yield and harvest index of mustard enhanced significantly with the increase in the level of applied sulphur upto 60 kg S/ha, whereas, harvest index under 40 kg S/ha stood at par with 20 kg S/ha.

The increase in yield attributes might be due to the fact that with increment in supply of S, the process of tissue differentiation from somatic to reproductive, meristematic activity and development of floral primodia might have increased more flowering and ultimately more siliquae. The cumulative effect of yield attributes led to higher seed yield under successive increase of sulphur levels upto 60 kg S/ha. The highest net return was fetched due to application of 60 kg/ha. These results confirm the findings of Chauhan *et al.* (1996) and Baldev Ram and Pareek (1999).

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J. Oilseeds Res., 23(2) : 222-224 (2006)

Groundnut-pigeonpea intercropping system under different plant density and fertility levels

R.M. Solanki, V.B. Bhalu and K.V. Jadav

Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat

(Received: March, 2005; Revised: August, 2005; Accepted: September, 2005)

Abstract

Effect of plant density and fertility levels on productivity and economic of groundnut-pigeonpea intercropping system under rainfed conditions was studied in maintaining 100 % plant density of base and intercrop with the application of 100 and 50% RDF to groundnut and pigeonpea, respectively under rainfed conditions for higher productions and economic returns.

Key words: *Groundnut, pigeonpea, intercropping* RDF, plant density

Introduction

There is an urgent need to increase the production of both oilseeds and pulses by adopting improved production practices. Groundnut-pigeonpea intercropping system is the most prevalent in semi-arid areas of the country. Groundnut makes rapid canopy coverage of the ground and uses the resources more effectively in the early stage. While pigeonpea is a long duration crop but its initial growth is very slow. The yield advantage of the intercropping system depends on the various agronomic requirements. Among them plant population of the base and component crops and fertilization which may vary with the cultivar and the soils of the region. However, little attention has been paid on this aspect while developing the management practices for an intercropping system. At the same time, reports are scanty on how an intercropping system alters nutrients and plant density requirement particularly under rainfed conditions. Therefore, the present investigation was planned to find out the optimum plant density and fertilizer levels in groundnut-pigeonpea intercropping system.

Material and methods

Field investigations were carried out at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh during *kharif-rabi* seasons from 2000-01 to 2002-03. The experimental soil was medium black in texture having 7.9 pH. It was low in available nitrogen (85.0 kg/ha), medium available phosphorus (23.5 kg/ha) and high in available potassium (386.0 kg/ha). The experiment was laid out in Randomized Block Design with three replications. The experiment consisted of 12 treatment combinations consisted of various proportions of plant density and fertility levels for groundnut and pigeonpea (Table 1). The groundnut cv. GG-2 and pigeonpea cv. BDN-2 were sown immediately after onset of monsoon in 3:1 row proportion at 45 cm row spacing, whereas, plant to plant distance was maintained according to plant density treatments. Full dose of fertilizers as per treatments was applied as basal in the previously opened furrows. Two supplementary irrigations were given to pigeonpea after harvesting of the groundnut crop. The other cultural operations were carried out as per recommendations made for base and intercrop in the region. Pod, haulm and seed yield of pigeonpea were recorded from each net plot and converted on hectare basis and total production of the system were presented in terms of groundnut pod equipment yield (PEY) as per Solanki *et al.* (2006).

Growth and yield attributing characters *viz.*, shelling %, test weight and oil content of groundnut and plant height, number of branches and pods/plant of pigeonpea were recorded from randomly selected five plants from each plot.

The rainfall received was 560.3, 532.4 and 1007.7 mm with 51, 21 and 39 rainy days during 2001, 2002 and 2003, respectively. While maximum temperature during crop seasons ranged between 36.3-29.8, 38.7-30.7 and 36.9-29.4 C°C, accordingly. Corresponding values of minimum temperature were 27.0-12.5, 27.3-14.1 and 27.0-12.1 C°C.

Results and discussion

Growth, yield and quality parameters: Combination of various fertility levels and plant density of groundnut and pigeonpea failed to exert their remarkable influence on shelling %, 100-seed weight and oil content in groundnut and number of pods/plant and plant height of pigeonpea (Table 1). The findings are in conformity with the results of Reddy *et al.* (1987).

Yield and economics: Maintaining 100% plant density of base and 50% plant density of intercrop with fertilizing

base and intercrop with 100 and 50% RDF to respective crops (Table 2) produced significantly highest pod yield (887 kg/ha) which was at par with 100% plant density of both the crops and application of 100% RDF to both the crops (T_1), 100% plant density of both the crops with the application of 100 and 50% RDF to base and intercrop (T_2), 75 and 50% plant density of base and intercrop with the fertilization of 50% RDF to both the crops (T_3) and base crop sown with 100% and intercrop with 50% plant density and both the crops were fertilized 50% RDF (T_{12}). Similarly, maximum haulm yield of 1462 kg/ha was recorded when base and inter crop was sown with 100 and 50% plant density with the application of 50% RDF to both the crops (T_{12}) which remained at par when base crop was sown at 100% plant density under all the density levels of intercrop and base crop received 100 or 50% RDF and intercrop fertilized with 50% RDF (T_1, T_5, T_9, T_{10} and T_{11}).

In case of pigeonpea seed yield (Table 2), it was significantly highest when base and inter crops were sown at 75 and 100% plant density with the application of 100 and 50% RDF to respective crops (T_3). Though it was at par with 100% plant density of both the crops when base crops were fertilized with 100% RDF and pigeonpea received 100 or 50% RDF (T_1 and T_2) and base and intercrop sown with 75 and 100% plant density and both the crops fertilized with the 50% RDF (T^4). Similarly, maximum groundnut pod equivalent yield (2319 kg/ha), gross (Rs. 41730/ha) and net realisation (Rs. 23446/ha) and CB ratio of 2.28 was obtained when each crop was maintained with 100% plant density and base and inter crop fertilized with 100 and 50% RDF, respectively (T_2) which remained statistically at par with T_1 (i.e., 100% plant density and RDF to both the crops) and T_3 (i.e., 75 and 100% plant density along with 100 and 50% RDF to base and intercrop, correspondingly). The higher yield of groundnut under 100 and 50% plant density with the application of 100 and 50% RDF to base and intercrop, respectively might be due to early vigorous and rapid growth and better resources utilizing ability of groundnut. While, maximum yield of pigeonpea produced under 75 and 100% plant density when groundnut and pigeonpea received 100 and 50% RDF, respectively which is due to better competitive ability of pigeonpea in the system and its recovery after harvest of base crop of groundnut (Reddy and Havanagi, 1986). Similar results were also reported by Thakur *et al.* (1998) and Hegde and Kiresur (1999).

Table 1 **Growth and yield attributes of groundnut and pigeonpea and economics as influenced by various plant density and fertility levels in groundnut-pigeonpea intercropping system (mean of three years)**

Treatment	Plant density (%)		Fertility levels (RDF %)		Groundnut			Pigeonpea			Realisation (Rs/ha)			
	Groundnut	Pigeonpea	Groundnut	Pigeonpea	Shelling (%)	Test weight (g)	Oil content (%)	No. of pods/ plant	Plant height (cm)	No. of branches/ plant	Gross	Cost	Net	C:B ratio
T_1	100	100	100	100	76	36.0	46.5	232	154	8.7	39948	19035	20913	2.10
T_2	100	100	100	50	76	36.0	46.3	247	155	9.0	41738	18292	23446	2.28
T_3	75	100	100	50	76	35.6	45.5	252	153	7.1	38436	17292	21144	2.22
T_4	75	100	50	50	76	35.5	45.8	243	147	7.2	35834	16970	18864	2.11
T_5	75	75	100	50	76	35.9	46.9	243	148	6.7	36799	17192	19607	2.14
T_6	75	75	50	50	75	35.3	47.2	251	143	7.6	35646	16870	18776	2.11
T_7	75	50	100	50	76	35.6	46.9	248	151	7.2	34073	17142	16931	1.99
T_8	75	50	50	50	77	36.2	46.7	227	151	7.5	34190	16820	17370	2.03
T_9	100	75	100	50	75	36.0	46.6	255	145	8.2	35711	17870	17841	2.00
T_{10}	100	75	50	50	76	35.1	45.6	259	152	7.9	35789	17870	17919	2.00
T_{11}	100	50	100	50	76	36.0	46.2	282	145	7.9	34813	18142	16671	1.92
T_{12}	100	50	50	50	76	36.5	46.1	255	150	7.3	35324	17820	17504	1.98
	CD (P=0.05)				NS	NS	NS	NS	NS	0.95	4032			
	CV (%)				3.02	6.27	2.0	12.5	3.5	12.3	11.8			

Table 2 **Pod, haulm and pigeonpea seed yield as well as pod equivalent yield as influenced by plant density and fertility levels of groundnut and pigeonpea in groundnut-pigeonpea intercropping system**

Treatment	Pod yield (kg/ha)				Haulm yield (kg/ha)				Pigeonpea seed yield (kg/ha)				Pod equivalent yield (kg/ha)			
	2001	2002	2003	Pooled	2001	2002	2003	Pooled	2001	2002	2003	Pooled	2001	2002	2003	Pooled
T_1	844	753	706	768	714	1272	1796	1269	1283	1602	1501	1462	2097	2337	2224	2219
T_2	799	932	714	815	858	1086	1741	1228	1273	1512	1775	1520	2048	2421	2487	2319
T_3	684	512	644	613	809	1204	1500	1171	1221	1663	1743	1542	1882	2150	2374	2135
T_4	689	537	702	639	722	1093	1414	1076	1186	1600	1316	1367	1840	2109	2024	1991
T_5	797	815	646	753	858	1370	1562	1263	1081	1552	1247	1293	1866	2356	1910	2044
T_6	664	703	744	737	691	932	1776	1000	1175	1583	1013	1257	1913	2250	1778	1980
T_7	927	593	733	751	735	907	1444	1029	976	1270	1199	1148	1890	1843	1948	1893
T_8	827	809	722	789	772	1148	1370	1097	697	1351	1295	1114	1520	2146	2021	1899
T_9	775	716	754	748	914	1313	1963	1403	1080	1462	1134	1225	1646	2171	1935	1984
T_{10}	839	654	799	764	827	1401	2000	1409	895	1447	1297	1213	1731	2099	2135	1988
T_{11}	932	820	927	887	808	1568	1914	1430	857	1290	926	1024	1786	2108	1908	1934
T_{12}	891	784	805	826	833	1580	1975	1462	860	1238	1251	1116	1750	2048	2096	1962
CD (P=0.05)	NS	NS	NS	121.2	NS	229.8	216.6	226.8	NS	240.1	351.3	197.7	NS	NS	NS	224.0
Interaction (YxT)				Sig.				Sig.				Sig.				Sig.
CD (P=0.05)				208.4				345.2				326.8				386.9

Sig. = Significant

Interaction effect: Interaction between years and treatments was significant with respect to haulm and pigeonpea seed yield (Table 2). The data indicated that when base and inter crop was sown with 100 and 50% plant density and crops were fertilized with 50% RDF of respective crop (T_{12}) produced maximum haulm yield of 1580 kg/ha during 2002, which was at par with T_5, T_{10} and T_{11}. During 2003, groundnut sown with 100 and pigeonpea with 75% plant density and application of 50% RDF to both the crops (T_{10}) recorded maximum haulm yield of 2000 kg/ha and found at par with T_1, T_6, T_9, T_{11} and T_{12}. In case of pigeonpea seed yield, maintaining 100% plant density of pigeonpea with 100 or 75% plant density of groundnut and base and intercrops fertilized with 100 and 50% RDF of respective crops (T_2 and T_3) remained statistically on same bar with T_4, T_5, T_6, T_9 and T_{10} during 2002 and T_1 and T_3 during 2003.

Conclusions: It can be concluded that groundnut and pigeonpea can be sown as intercrop with maintaining 100% plant density of both the crops and fertilized 100 and 50% RDF to groundnut and pigeonpea, respectively for higher total production and gross realisation under rainfed conditions of South Saurashtra agro-climatic region.

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J. Oilseeds Res., **23**(2) : 225-229 (2006)

Productivity of groundnut-castor intercropping system as influenced by row ratio, sowing time and hybrids of castor, *Ricinus communis* L.

R.M. Solanki, V.B. Bhalu and K.V. Jadav

Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat

(Received: March, 2005; Revised: September, 2005; Accepted: October, 2005)

Abstract

Studies on row ratio and sowing time of castor hybrid in groundnut-castor intercropping system revealed that groundnut- castor sown in 3 : 1 row ratio produced maximum pod, haulm and oil yield of groundnut. Difference in castor seed and groundnut pod equivalent yield between row ratios were non significant. Sowing of castor as an inter crop 45 days after sowing of groundnut recorded significantly maximum pod and haulm yields. Significantly maximum castor seed (1857 kg/ha) and pod equivalent yield (3218 kg/ha) as well as gross and net realization with 2.67 C:B ratio were obtained when groundnut and castor crop were sown simultaneously. Sowing of castor hybrid GCH-4 as an inter crop produced highest pod, castor seed and pod equivalent yield with maximum gross and net return with 2.59 C:B ratio. Growth and yield attributing characters of base and inter crops were not influenced significantly due to row ratio. Test weight of groundnut was observed maximum when castor sown as an inter crop 45 DAS of groundnut. Test weight of groundnut was noted higher when castor hybrid GCH-6 as inter crop. Significantly higher oil yield of castor and spikes/plant were recorded in GCH-4 hybrid sown as inter crop.

Key words: Groundnut, castor, intercropping, row ratio, sowing time, hybrid

Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop of India and fetches a sizeable amount of foreign exchange to the country (Tewari, 1994). The crop is unique in its adaptation to variety of soils with poor fertility and aberrant weather. This owes to its hardy growth with deep tap-root system. It is a long duration crop (210-240 days) with slow growth habit in the initial stages and it is grown in wider rows with a spacing of 90-180 cm. These features offer a potential scope to intercrop with short duration crop like groundnut to exploit the land and resources more efficiently particularly under Saurashtra region of the Gujarat wherein groundnut is the major rain fed crop cultivated during *kharif* season. The average productivity of the inter cropping system depends on various agronomic requirements of base and inter crops. This warrants an evaluation of optimum row ratio and sowing time of castor hybrids in groundnut-castor intercropping system and hence, present experiment was conducted.

Material and methods

The field experiment was carried out at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh (Gujarat) during *kharif-rabi* seasons of 2000-2001 and 2001-2002.The experimental soil was medium black in texture having low available N (88.5 kg/ha), medium available P_2O_5 (28.5 kg/ha) and high available K_2O (386.5 kg/ha) with pH-7.9. Twelve treatment combinations consisting of two row ratio of groundnut-castor (*viz.*, R1-2:1 and R2-3:1), three sowing time of castor hybrid (*viz.*, D_1-simultaneous sowing of groundnut and castor, D_2 - castor sown 25 DAS *groundnut and* D_3- *castor sown* 45 DAS groundnut) were tested in Factorial Randomized Block Design with three replications. Fertilizers were applied as per recommendation to groundnut (12.5-25.0-00 NPK kg/ha) before sowing the crop. Half dose of nitrogen and full doze of phosphorus as per recommendation (75.0 -50.0-00 NPK kg/ha) on actual area basis to castor were applied before sowing the castor as basal and remaining half doze of nitrogen was applied in two equal splits at 40 and 70 days after sowing the crop. Groundnut cv. GG-5 was sown in previously opened furrows at 45 cm spacing as soon as sufficient rainfall received. Castor hybrids were sown by dibbling as per row ratio and sowing time. Two supplementary irrigations were applied to castor after harvest of groundnut. Five plants were randomly selected from each plot for recording growth and yield attributing characters of castor *viz.*, plant height and number of spikes/plant. Whereas yield/hectare were computed from the each net plot and economics were worked out on the basis of current prices of produce and inputs used and groundnut pod equivalent yield as per formula:

$$\text{PEY (kg/ha)} = \frac{\text{Seed price of castor (Rs/kg)}}{\text{Pod price of groundnut (Rs/kg)}} \times \text{Seed yield of castor (kg/ha)} \times \text{Pod yield of groundnut (kg/ha)}$$

The rainfall received was 560.3 mm with 28 rainy days during 2000-01 while it was 855.6 mm with 51 rainy days during 2001-02. Nearly 35% of total rainfall received during month of June-2001-02.

Results and discussion

Effect of row ratio: Groundnut-castor sown in 3:1 row ratio produced significantly highest pod yield of 1854 and 1612 kg/ha during 2001-02 and in pooled results and haulm yield of 2270 and 2021 kg/ha during 2000-01 and in pooled results, respectively. The per cent increase in pod and haulm yields due to 3:1 row ratio over 2 : 1 row ratio was to the tune of 9.5 and 6.8%, accordingly on pooled data basis (Table 1). The seed yield of castor was unaffected due to row ratio, except during 2000-01 wherein groundnut-castor sown in 2:1 row ratio produced maximum seed yield of 1386 kg/ha. Differences in groundnut pod equivalent yield and gross realization due to row ratio were non significant during individual years as well as in pooled results (Table 2). The growth and yield attributes of groundnut and castor *viz.*, plant height, number of spikes/plant and test weight of castor and shelling percentage and test weight of groundnut had no significant influence of row ratio (Table 2 and 3), while oil yield of groundnut was maximum (522 kg/ha) when groundnut-castor sown in 2:1 row ratio on pooled results. Agasimani *et al.*, (1994) reported that groundnut-castor sown in 3 : 1 row ratio produced higher castor yield than 6 : 1 and 9 : 2 row ratios.

Effect of castor sowing time: Castor sown 45 DAS of groundnut (D_3) as inter crop produced maximum pod and haulm yields (Table 2). Castor sown 25 or 45 DAS of groundnut (D_2 or D_3) produced comparable pod and haulm yields during 2000-01 (Table 1). The per cent increase in pod and haulm yields due to sowing of castor 45 DAS of groundnut (D_3) was to the tune of 35.6 and 27.8%, respectively over simultaneous sowing of both the crops on pooled data basis. Groundnut and castor sown at the time of onset of monsoon (D_1) recorded significantly maximum castor seed yield of 2406, 1309 and 1857 kg/ha during 2000-01, 2001-02 and in pooled results, respectively, while corresponding groundnut pod equivalent yield were 3433, 3003 and 3218 kg/ha and found at par with sowing of castor as an inter crop 25 DAS of groundnut (D_2) during 2001-02. Simultaneous sowing of groundnut and castor (D_1) produced 201.9 and 124.6% higher castor seed and groundnut pod equivalent yield, respectively than castor sown 45 DAS of groundnut (D_3) on pooled data basis. Sowing of base and inter crop at the time of onset of monsoon obtained maximum gross realization of Rs 45056/ha and higher net return of Rs.28156/ha with 2.67 C:B ratio. Test weight in groundnut was observed maximum of 43.26g when castor sown 45 DAS of groundnut on pooled data basis (Table 2) Venkateswaralu and Subba Reddy (1989) reported that yield of base and component crop were recorded significantly highest when both the crops were sown timely.

Effect of castor hybrid: Differences in the growth and yield attributes of groundnut and castor *viz.*, plant height, number of spikes/plant, test weight of castor and shelling percentage, test weight and oil yield of groundnut were non significant due to castor hybrids except, test weight of groundnut was maximum of 44.0 and 43.1 g during 2001-02 and in pooled, respectively when castor hybrid GCH-6 was sown as inter crop. While oil yield of groundnut was maximum of 471 kg/ha when castor hybrid GCH-4 was sown as inter crop. However, number of spike/plant was higher when GCH-4 was sown as inter crop during individual years as well as in pooled results. Sowing of castor hybrid GCH-4 as inter crop with groundnut produced maximum pod (1612 kg/ha), castor seed (1310 kg/ha), groundnut pod equivalent yield (3080 kg/ha) and oil yield of castor (655 kg/ha) on pooled data basis which was 9.5, 30.9, 17.8 and 35.6 per cent higher than castor hybrid GCH-6 sown as inter crop (Table 1).

The maximum gross and net realization with C:B ratio of 2.59 were obtained when GCH-4 was inter cropped with groundnut (Table 2).

Interaction effect between row ratio and sowing time: Significant interaction effect between row ratio and sowing time of castor on pod and haulm yield (Table 4) indicated that pod (1709 kg/ha) and haulm yield (1961 kg/ha) during 2000-01 and 2001-02, respectively were produced when castor sown 45 DAS of groundnut in 3:1 row ratio. Similarly, groundnut pod equivalent yield (3500 kg/ha) was observed maximum when base and inter crop sown simultaneously in 3:1 row proportion and remained at par with 2:1 row ratio (Table 4). Patel *et al.* (2005) also reported that early sowing of castor gave higher seed yield irrespective of castor hybrids.

Interaction effect of row ratio, sowing time and variety of castor: Interaction effect among row ratio, sowing time and variety of castor were observed significant for haulm, castor seed and oil yield of castor (Table 5). Results showed that sowing of castor hybrid GCH-6 45 DAS of groundnut in 3:1 row proportion produced maximum haulm yield during 2001-02 than rest of the sowing time of castor. Significantly higher seed (2187 kg/ha) and oil yield of castor (1091 kg/ha) recorded when groundnut and castor cv. GCH-4 were sown simultaneously in 3:1 row ratio which was found at par when groundnut and castor (cv. GCH-4) sown simultaneously in 2:1 row ratio.

Table 1 Pod, haulm, castor seed and groundnut pod equivalent yields as influenced by row ratio, sowing time hybrid of castor in groundnut-castor intercropping system

Treatment	Pod yield (kg/ha)			Haulm yield (kg/ha)			Castor seed yield \(kg/ha)			Groundnut pod equivalent yield (kg/ha)		
	2000-01	2001-02	Pooled	2000-01	2001-02	Pooled	2000-01	2001-02	Pooled	2000-01	2001-02	Pooled
Row ratio												
R_1- 2:1	1296	1648	1472	2050	1734	1892	1386	1052	1219	2870	2810	2840
R_2- 3:1	1371	1854	1612	2270	1772	2021	1173	1037	1105	2703	3006	2854
SEm ±	49.4	31.4	29.3	53.8	22.4	29.1	39.9	56.1	34.4	85.2	74.3	56.5
CD (P=0.05)	NS	92.2	83.6	157.9	NS	83.1	116.8	NS	NS	NS	NS	NS
Sowing time of castor												
D_1- Simultaneous	1005	1620	1313	1810	1585	1698	2405	1309	1857	3433	3003	3218
D_2-25 DAS to D_1	1422	1646	1534	2282	1721	2001	841	1187	1014	2548	2932	2740
D_3-45 DAS to D_1	1573	1987	1780	2390	1952	2171	593	638	615	2379	2787	2583
SEm ±	60.5	38.5	50.7	65.9	27.4	50.5	48.8	68.7	59.6	104.4	91.0	97.9
CD (P=0.05)	175.8	113.0	144.6	193.4	80.4	144.0	143.1	201.5	169.9	306.2	NS	279.3
Hybrid of castor												
V_1- GCH-4	1440	1784	1612	2160	1759	1960	1473	1162	1318	3106	3055	3080
V_2- GCH-6	1226	1718	1472	2160	1747	1954	1087	926	1007	2467	2761	2614
SEm ±	49.4	54.5	29.3	53.8	22.4		39.9	56.1	34.4	85.2	74.3	56.5
CD (P=0.05)	144.8	NS	83.6	NS	NS	NS	116.8	164.6	98.1	250.0	218.0	161.2
Interaction R x D	SIG	NS	NS	NS	SIG	NS	NS	NS	NS	SIG	NS	NS
Interaction R x D x V	NS	NS	NS	NS	SIG	NS	NS	NS	SIG	NS	NS	NS
Interaction Y x D			SIG			SIG			SIG			SIG
SEm ±			50.7			50.5			59.6			97.9
CD (P=0.05)			144.6			144.0			170.0			279.3

Table 2 Shelling, test weight, oil yield of groundnut and economics as influenced by row proportion, sowing time and hybrid of castor in groundnut-castor intercropping system

Treatment	Shelling (%)			Test weight (g)			Oil yield (kg/ha)			Realisation (Rs/ha)			C:B ratio
	2000-01	2001-02	Pooled	2000-01	2001-02	Pooled	2000-01	2001-02	Pooled	Gross	cost	Net	
Row ratio													
R_1- 2:1	76.2	78.6	77.4	41.1	43.2	42.2	418	538	478	39788	16117	23671	2.47
R_2- 3:1	75.7	78.2	78.0	42.1	43.4	42.8	437	608	522	39966	17216	22750	2.32
SEm ±	0.3	0.3	0.2	0.4	0.3	0.2	17.7	11.7	10.6	790			
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	34.4	30.3	NS			
Sowing time of castor													
D_1- Simultaneous	76.1	78.3	77.2	41.9	43.3	42.6	315	528	422	45056	16900	28156	2.67
D_2-25 DAS to D.	76.2	78.5	77.3	40.9	42.3	41.6	462	540	501	38406	16700	21706	2.30
D_3-45 DAS to D_1	75.7	78.5	77.1	42.2	44.4	43.3	506	650	578	36168	16400	19768	2.21
SEm ±	0.4	0.3	0.3	0.5	0.3	0.3	21.7	14.4	33.9	1368			
CD (P=0.05)	NS	NS	NS	NS	1.0	0.8	63.6	42.1	NS	3900			
Hybrid of castor													
V_1- GCH-4	76.1	78.4	77.2	41.1	42.6	41.9	471	579	525	43129	16667	26462	2.59
V_2- GCH-6	75.9	78.5	77.2	43.1	44.0	43.1	385	566	476	36625	16667	19958	2.20
SEm ±	0.3	0.3	0.2	0.4	0.3	0.2	17.7	11.7	25.8	790			
CD (P=0.05)	NS	NS	NS	NS	0.8	0.7	51.9	NS	NS	2252			
Interaction R x D			NS			NS	SIG	NS	NS	NS			
Interaction R x D x V			NS			NS	NS	NS	NS	NS			
Interaction Y x D			NS			NS			SIG	SIG			
SEm ±									18.4	1368			
CD (P=0.05)									52.5	3901			

Table 3 Plant height, number of spikes, test weight and oil yield of castor as influenced by row proportion, sowing time and hybrid of castor in groundnut-castor intercropping

Treatment	Plant height (cm)			No. of spikes/plant			Test weight (g)			Oil yield (kg/ha)		
	2000-01	2001-02	Pooled	2000-01	2001-02	Pooled	2000-01	2001-02	Pooled	2000-01	2001-02	Pooled
Row ratio												
R_1- 2:1	77	78	77	3.6	3.7	3.6	26.9	43.2	35.4	663	531	597
R_2- 3:1	78	76	77	3.5	3.3	3.4	26.5	42.9	34.8	560	522	541
SEm ±	1.7	1.9	1.3	0.1	0.1	0.1	0.4	0.9	0.5	19.2	28.4	17.1
CD (P=0.05)	NS	NS	NS	NS	0.3	NS	NS	NS	NS	56.2	NS	NS
Sowing time of castor												
D_1- Simultaneous	88	77	82	5.3	4.3	4.8	26.7	43.3	35.0	1160	661	911
D_2-25 DAS to D_1	81	94	88	3.1	4.0	3.5	27.5	42.8	35.2	400	595	498
D_3-45 DAS to D_1	69	61	62	2.2	2.2	2.2	25.8	43.1	34.5	273	323	298
SEm ±	2.1	2.3	5.8	0.2	0.1	0.5	0.5	1.0	0.6	23.5	34.7	182.9
CD (P=0.05)	6.2	6.8	NS	0.4	0.4	NS	1.3	NS	NS	68.9	101.9	NS
Hybrid of castor												
V_1- GCH-4	82	76	79	3.9	3.9	3.9	26.7	43.5	35.1	719	591	655
V_2- GCH-6	73	76	76	3.2	3.1	3.1	26.8	43.6	34.7	503	462	483
SEm ±	1.7	1.9	4.3	0.1	0.1	0.1	0.4	0.9	0.5	19.2	28.4	17.1
CD (P=0.05)	5.1	NS	NS	0.4	0.3	0.2	NS	NS	NS	56.2	83.2	48.8
Interaction R x D			NS	NS	NS	NS			NS	NS	NS	NS
Interaction R x D x V			NS	NS	NS	NS			NS	NS	NS	SIG
Interaction Y x D			SIG			SIG			NS			SIG
SEm ±			2.22			0.14						29.6
CD (P=0.05)			6.33			0.39						84.6

Table 4 Interaction effect between row ratio and sowing time of castor

Treatment	Pod yield (kg/ha)		Haulm yield (kg/ha)		Pod equivalent yield (kg/ha)		Oil yield (kg/ha)	
	Row ratio							
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
Date of sowing	2000-01		2001-02		2000-01		2000-01	
D_1	904	1106	1643	1527	3366	3500	291	339
D_2	1547	1296	1618	1826	2892	2204	511	413
D_3	1435	1709	1942	1961	2351	2407	453	558
SEm ±		85.5		38.8		147.6		36.7
CD (P=0.05)		250.9		113.7		433.0		90.0

Table 5 Interaction effect of row ratio, sowing time and hybrids of castor

Treatment	Haulm yield (kg/ha)				Castor seed yield (kg/ha)				Oil yield (kg/ha)			
	Row ratio											
	R_1		R_2		R_1		R_2		R_1		R_2	
	Castor hybrid											
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
Date of sowing												
D_1	1625	1661	1650	1404	2009	1753	2187	1479	1004	833	1091	715
D_2	1661	1570	1805	1847	1261	945	1016	832	633	458	502	397
D_3	1877	2007	1932	1990	799	545	632	485	392	263	308	231
SEm ±				54.8				84.3				41.9
CD (P=0.05)				160.8				240.4				119.6

Conclusion: It can be concluded that groundnut and castor hybrid GCH-4 can be sown simultaneously as inter crop with 2:1 or 3:1 row proportion for realizing higher total yield and gross realization under South Saurashtra agroclimatic condition.

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J. Oilseeds Res., 23(2) : 230-233 (2006)

Direct, residual and cumulative effects of applied zinc in rice-sunflower system

M.C. Patnaik, A. Sreenivasa Raju and G. Bhupal Raj

AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soil and Plants, Agril. Research Institute, Rajendranagar, Hyderabad-500 030, AP

(Received: June, 2005; Revised: October, 2005; Accepted: December, 2005)

Abstract

The direct, residual and cumulative effects of applied zinc in rice sunflower system was studied in an Alfisol during 2000-02 at Students' Farm, Rajendranagar, Hyderabad with five treatments (*viz.*, 0, 25, 50, 75, and 100 kg $ZnSO_4$/ha). Hybrid rice was transplanted during *kharif*, 2000 for knowing the direct effect of zinc. Subsequent crops in the sequence of two years were sown during *rabi* season for knowing the residual effects. Additional application of zinc was done during third season to know the cumulative effect of added Zn on third crop of rice and also its residual effects on the subsequent sunflower crop. Significant influence of zinc was seen only upto 50 kg $ZnSO_4$/ha in direct crop of hybrid rice. The dose can be increased to 75 kg $ZnSO_4$/ha when the second crop in the sequence is sunflower. An additional dose of 25 kg $ZnSO_4$/ha added to the initial dose of 75 kg $ZnSO_4$/ha can significantly meet the requirement of fourth crop of sunflower. Significant improvement in the oil content was recorded in sunflower over control by the zinc application to the preceding crop of rice. There was a built up in the available zinc status of soil by 11.63% in the surface soil.

Key words: Direct, residual and cumulative, Zn, hybrid rice, available zinc

Introduction

Zinc, an essential micronutrient has played an important role in enhancing the crop production in our country, which even in minute quantities is indispensable for ensuring proper growth and yield of crops. Though studies on zinc availability in soils and zinc requirement of individual crops are plenty, the information on crops involved in cropping systems is meager, especially on hybrid rice-sunflower system grown on Alfisols of Southern Telangana Zone, which occupy about 65% of states' land area (Subba Rao and Adinarayana, 1995) and are deficient in zinc to about 46% and also information on its availability. Hence, the present investigation was planned to study the requirement of zinc in rice-sunflower system grown on Alfisols of Southern Telangana zone.

Material and methods

Field experiments were conducted for two consecutive years in Students' Farm, College of Agriculture, Rajendranagar, Hyderabad during 2000-01 and 2001-02 on zinc deficient Alfisols to know the direct and residual effects of applied zinc on yield, zinc nutrition of crops involved in the system and also to know the depletion of zinc by the crops involved in hybrid rice based cropping system i.e., hybrid rice-sunflower. The experiments were laid out in a Randomized Block Design with five Zn treatments and each replicated five times (Table 1). The experimental soil was slightly alkaline (pH 7.8), normal in soluble salt content (0.17 dS/m), low in organic carbon content (5.9 g/kg) and nitrogen (189 kg/ha), medium in available phosphorus (21.07 kg/ha), high in available potassium (325 kg/ha). Available Zn content in soil was 0.58 mg/kg which was deficient.

Hybrid rice (APHR-2) was transplanted during *kharif* season of 2000 for knowing the direct effect of applied zinc on rice crop with the five Zn treatments. After the harvest of rice crop, sunflower (var. Morden) was sown during *rabi* season of 2000-01 in the same plots where hybrid rice was grown to know the residual effects of zinc. The plots after the harvest of *rabi* crop of sunflower was ploughed thoroughly and each plot was made into sub-plots. One sub-plot was left out without zinc application to study the residual effects while the others were utilized for studying the cumulative effects of applied zinc. The plots meant for studying the cumulative effect were applied uniformly with zinc sulphate @ 25 kg/ha.

Third crop of hybrid rice was planted during the *kharif*, 2001 in above mentioned plots for knowing both the second residual and cumulative effects of zinc. After the harvest of third crop of hybrid rice, sunflower was sown during, *rabi*, 2001-02 in the plots used for growing rice during the previous

season so that third residual effects of initially applied zinc fertilizer and first residual effect of the additionally added zinc (cumulative residual) could be known.

Plant samples were collected at harvest stage in case of the hybrid rice and sunflower. Grain and straw yields were recorded at harvest in hybrid rice. Seed and stalk yields were recorded at harvest in sunflower. Oil content (%) in sunflower was also estimated (Tiwari *et al.*, 1974). Soil samples were collected from each plot simultaneously from two depths (0-15 and 15-30 cm). The plant as well as soil samples were processed and analysed for the zinc content in soil and its concentration in plants (Jackson, 1973).

Results and discussion

Direct effect of applied zinc on hybrid rice: There was a significant increase in grain and straw yields of rice upto Zn_{50} level and thereafter the yields did not increase significantly due to enhanced application of Zn above 50 kg $ZnSO_4$/ha level and were on par with each other (Table 1). Grain yield of rice increased from 5879 to 7136 kg/ha with a mean of 6721 kg/ha and with an increase by 17.9% over Zn_0. Total Zn uptake values were found significantly different with each other. Highest Zn uptake of 592.14 g/ha was recorded at Zn_{100} level while it was 248.26 g/ha at Zn_0 level. The results are in conformity with those reported by Bhupal Raj *et al.* (2000).

Residual effects of zinc: Significant effect of zinc was seen on the 2nd residual crop of hybrid rice also and the effect was significant upto Zn_{75} level beyond which there was a non-significant increase in yield at Zn_{100} level over Zn_{75}. The mean grain yield of rice recorded due to residual effect of applied Zn was 5773 kg/ha. There was a reduction in yield by 951 kg/ha due to the residual effect over the direct effects. Mean zinc uptake by the residual crop of rice was lower (303.5 g/ha) when compared with the direct crop (429.3 g/ha) showing a reduction of 115.7 g/ha.

Cumulative effect of applied zinc: There was a decrease in response due to the additional application of zinc. Significant increase in grain and straw yields of rice was recorded by the additional application of 25 kg $ZnSO_4$/ha to the initial level of 75 kg $ZnSO_4$/ha. An added dose of 25 kg $ZnSO_4$/ha to 100 kg initial level did not affect the grain yield of rice significantly. The mean grain yield of rice at harvest was 6699 kg/ha. There was an increase in the grain yield of rice by 926 kg/ha over the residual effect of zinc.

Zinc uptake also increased significantly by the additional dose of zinc. Total zinc uptake varied from 308.0 to 533.6 g/ha, with a mean of 429.6 g/ha. Total zinc uptake also increased significantly due to application of zinc at different levels. Hoque and Jahiruddin (1994) also reported similar findings in rice-rice system.

Residual effect of zinc applied to rice on sunflower: Significant effect of applied zinc was observed on seed yield of sunflower upto Zn_{75} level, with a non-significant effect at Zn_{100} level. The seed yield varied from 1309 to 1653 kg/ha with a mean of 1504 kg/ha. Total zinc uptake by sunflower increased significantly with the level of zinc addition. The sunflower crop recorded mean uptake of 112.6 g/ha within the range of 75.5 to 156.7 g/ha (Table 2). Trehana and Sharma (2000) also reported similar findings.

Significant increase was also seen in the seed yield of third residual crop of sunflower due to different levels of applied zinc. The increase in seed yield varied from 1182 to 1633 kg/ha with a mean of 1415 kg/ha. The seed yield in third crop of sunflower reduced to 89 kg/ha over the first sunflower crop.

The zinc uptake varied from 75.5 to 156.7 g/ha with a mean of 112.6 g/ha. The zinc uptake reduced to 20.8 g/ha in seed in the fourth residual crop of sunflower. There was a reduction by 18.5% in the total zinc uptake over the second crop of sunflower.

Cumulative residual effect of added zinc on sunflower: Significant effect of zinc applied to the third crop of rice was observed on the seed yield of fourth crop of sunflower and the residual effect was significant only upto Zn_{75+25} beyond which it was not significant. The mean seed yield recorded was 1618 kg/ha (Table 2). There was an increase in yield to an extent of 14.3% over the fourth residual crop of sunflower.

There was a significant increase in the zinc uptake too in the sunflower due to the cumulative effect of added zinc to the third crop, which was on par with the yield obtained at Zn_{100+25}. There was nearly one and half times increase in total zinc uptake at the maximum zinc levels. Patnaik and Bhupal Raj (1999) also reported that zinc application was found to result in significant residual effects on the zinc concentration and uptake by the end of 3rd and 4th crops grown in sequence on Alfisols.

Effect of applied zinc on oil content of sunflower: Significant improvement in oil content was seen over control in the sunflower because of zinc applied to preceding rice crop. Zinc application over the above 50 kg $ZnSO_4$/ha did not influence the oil content of sunflower seed. The mean oil content recorded was 42.9%. The variations in content being 40.0 to 43.5%. The oil content was also significantly influenced due to application of zinc to rice on third residual crop of sunflower grown rice-sunflower sequence. Different levels of applied zinc resulted in a mean oil content of 41.8% in the third residual crop with a non-significant difference among different zinc levels beyond the level of 50 kg $ZnSO_4$ (Table 3). The above results are in agreement with those reported by Wankhade *et al.* (1997).

Table 1 Direct, residual and cumulative effects of applied zinc on hybrid rice

Treatment $ZnSO_4$ (kg/ha)	Grain yield (kg/ha)			Uptake (g/ha)		
	Direct	1st Residual	Cumulative	Direct	1st Residual	Cumulative
0	5879[a]	4982[a]	6210[a]	248.4[a]	203.8[a]	308.0[a]
25	6469[b] (10)	5519[b] (10.8)	6431[b] (3.6)	345.1[b]	269.9[b]	374.9[b]
50	7017[c] (19)	5853[c] (17.4)	6739[c] (8.5)	442.3[c]	321.0[c]	439.6[c]
75	7102[c] (21)	6198[d] (24.4)	6982[d] (12.4)	518.4[d]	304.3[d]	492.1[d]
100	7136[c] (21.4)	6315[d] (26.8)	7133[d] (14.9)	592.1[e]	418.7[e]	533.6[e]
Mean	6721	5773	6699	429.3	303.5	429.6

Figures in parenthesis are per cent response over control.
Figures with the same letter are not significantly different (P=0.05) as per DMRT.

Table 2 Residual and cumulative residual effects of applied zinc on sunflower

Treatment $ZnSO_4$ (kg/ha)	Seed yield (kg/ha)			Uptake (g/ha)		
	1st Residual	3rd Residual	Cumulative	1st Residual	3rd Residual	Cumulative
0	1309[a]	1182[a]	1462[a]	75.5[a]	51.3[a]	110.3[a]
25	1433[b] (9.5)	1327[c] (12.4)	1548[b] (5.9)	85.3[b]	78.0[b]	132.6[b]
50	1520[c] (16.2)	1416[c] (19.8)	1636[c] (11.9)	113.9[c]	96.3[c]	151.1[c]
75	1610[d] (22.9)	1527[d] (29.2)	1724[d] (17.9)	131.9[d]	111.1[d]	168.7[d]
100	1653[d] (26.2)	1633[e] (38.1)	1748[d] (19.6)	156.7[e]	122.4[e]	182.8[e]
Mean	1504	1415	1618	112.6	91.8	149.1

Figures in parenthesis are per cent response over control
Figures with the same letter are not significantly different (P=0.05) as per DMRT

Table 3 Residual and cumulative residual effect of applied zinc on sunflower oil content (%)

Treatment $ZnSO_4$ (kg/ha)	Residual oil content (%)		Treatment $ZnSO_4$ (kg/ha)	Cumulative residual oil content (%)
	1st	3rd		
0	40.0	40.3	25	42.4
25	42.8	41.3	50	43.4
50	42.9	42.7	75	44.5
75	43.4	42.6	100	45.9
100	43.5	42.9	125	46.7
Mean	42.9	41.8	Mean	44.4
CD (P=0.05)	2.9	2.3	CD	2.9

The additional dose of 25 kg $ZnSO_4$ applied to the third crop of rice in the sequence influenced the oil content showing the cumulative residual effect. The mean oil content recorded was 44.4%. The probable reason for the enhancement in the oil content could be due to the application of zinc to the soil, which would have activated the NADPH dependent dehydrogenase involved in the fat synthesis by zinc.

Available zinc: There was significant influence of applied zinc on the available zinc status of all the crops in the sequence and the available zinc status decreased with the number of crops grown (Table 4). Similar observations were also reported by Sharma and Bhardwaj (1998) for rice-wheat and Patnaik and Bhupal Raj (1999) for rice-rice system.

The mean available zinc contents recorded after the harvest of direct and residual crops is 0.61, 0.60, 0.55 and 0.53 in the surface soil and 0.58, 0.54, 0.50 and 0.45 mg/kg in the sub-surface. By the cumulative addition of zinc the contents was increased from 0.55 (III crop) to 0.61 in the cumulative zinc added plots in the surface soil and 0.50 to 0.58 in the sub-surface soil. By the cumulative residual of added zinc the content was increased by 0.06 and 0.08 mg/kg at both the depths, respectively.

Effect of zinc application on the built up of soil available zinc: The available zinc status increased with the zinc application. The built up in available zinc status was upto 11.6% at surface and 16.1% at sub-surface soil level put to rice as direct crop. However, due to cumulative application of zinc, the mean built up was only 7.3% in 0-15 cm depth and it remained more or less same (15.0%) when compared with the 15-30 cm depth of direct crop of rice. The built up in the surface soil was less in plots of cumulative zinc applied treatments because of the depletion of zinc by the residual crops grown in the sequence prior to its application to the 2nd residual crop (Table 5).

Table 4 Direct, residual, cumulative and cumulative residual effects of applied zinc on content of available Zn under rice-sunflower cropping system

Treatment $ZnSO_4$ (kg/ha)	Direct rice	Residual			Treatment $ZnSO_4$ (kg/ha)	Cumulative rice	Cumulative residual sunflower
		Sunflower	Rice	Sunflower			
0-15 cm							
0	0.56	0.55	0.50	0.48	25	0.57	0.55
25	0.57	0.55	0.51	0.50	50	0.59	0.56
50	0.62	0.59	0.54	0.52	75	0.60	0.58
75	0.65	0.65	0.60	0.56	100	0.64	0.62
100	0.69	0.58	0.62	0.61	125	0.67	0.64
Mean	0.61	0.60	0.55	0.53	Mean	0.61	0.59
CD (P=0.05)	0.048	0.042	0.049	0.043	CD (P=0.05)	0.056	0.043
15-30 cm							
0	0.52	0.48	0.44	0.40	25	0.51	0.47
25	0.54	0.50	0.46	0.41	50	0.55	0.50
50	0.58	0.54	0.50	0.45	75	0.58	0.54
75	0.61	0.59	0.51	0.47	100	0.59	0.55
100	0.67	0.62	0.57	0.52	125	0.65	0.61
Mean	0.58	0.54	0.50	0.45	Mean	0.58	0.53
CD (P=0.05)	0.046	0.047	0.048	0.04	CD (P=0.05)	0.047	0.046

Table 5 Built up of available zinc (%) in soil in rice-sunflower cropping system

Soil depth	Crop	Built up (%)
Surface (0-15 cm)	Direct	11.6
	Cumulative	7.3
Sub-surface (15-30 cm)	Direct	16.1
	Cumulative	15.0

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J. Oilseeds Res., 23(2) : 234-238 (2006)

Use of soil amendments on productivity of sunflower, castor and sorghum in rainfed environment

G. Subba Reddy, V. Maruthi, M. Vanaja and M. Sree Rekha

Central Research Institute for Dryland Agriculture, Santoshnagar, Saidabad, Hyderabad-500 059, AP

(Received: May, 2001; Revised: May, 2006; Accepted: June, 2006)

Abstract

The studies on effect of soil amendments (FYM and Bentonite) on soil quality and crop growth in sunflower (MSFH-8) was conducted for four *kharif* seasons in rainfed alfisols. The residual effect of these amendments was studied with castor (GCH-4) and sorghum (CSH-6) in rotation during fifth and sixth years. Use of soil amendments on an average increased the seed yields of sunflower by 30-40% over the chemical fertilizer alone. Among the various amendments, FYM @ 10 t/ha/year recorded the highest seed yields followed by bentonite + FYM due to increased growth components and also better use of rainfall and nutrients. Set row application of FYM recorded additional seed grains (12-20%) compared to the broadcast. Use of soil amendments (FYM alone or in combination with bentonite) recorded significant residual effects of 44-56% in castor, sorghum in sequence. These amendments after application for four years substantially improved soil quality parameters like organic carbon, total nitrogen and phosphorus. Set row application of FYM showed higher direct effect on yield, nutrient and water use while there are no variations on yield and quality parameters of castor and sorghum due to residual effect of these amendments.

Key words: Organic amendments, residual effect, sunflower, castor, sorghum

Introduction

Organic manures are the valuable natural resources that can augment the nutrient supplies to starving rainfed crops. The major issues facing Indian agriculture today is enhancement of agricultural production and productivity in a sustainable manner. Maintaining soil health and fertility is essential under intensive cropping system to obtain sustainable high productivity. Exploitation of the potential of organic manures and their synergistic effect with chemical fertilizer is necessary for increasing productivity, sustainability of agriculture and also improving soil health and environmental security. Use of fertilizes in drylands is meagre because of its high cost, certainty of risk and poor economic conditions of the farmers. In rainfed environment fluctuation in yield is due to intermittent moisture and nutrient scarcity and soil organic amendments serve as source of nutrients. The efficacy of these amendments can be enhanced by appropriate methods and times of application. Therefore, it is imperative to make use of organic manures to maintain soil fertility and in sunflower, being an important commercial oilseed crops, maintaining its yield levels even under monocropping is crucial.

Material and methods

A field experiment was conducted from *kharif* for four years in rainfed alfisols of Central Research Institute for Dryland Agriculture, Hyderabad. There were seven treatments applied to sunflower cv. MSFH-8 in 60 cm set rows and non-set rows after adjusting to the level of 50-30-0 NPK kg/ha with chemical fertilizer (Table 1). The residual effects of soil amendments was studied with castor (cv. GCH-4) as a test crop in fifth year and rotated with sorghum (CSH-6) in sixth year in same plots. The soil was sandy loam in texture, low in available nitrogen (210 kg/ha), phosphorus (10 kg/ha) and medium to high in available potassium (210 kg/ha). The initial organic carbon % was 0.51 and 0.53 at 0-15 and 15-30 cm soil depth; while pH was 6.0 and 6.2 at these depths, respectively. The experiment was studied in Randomized Block Design and replicated five times. The growth parameters like drymatter, leaf area index (LAI), nitrogen uptake and yields of crops in different treatments were recorded during the growth stages of crop in each year. The yields of crops in various treatments were recorded in all the years to evaluate the response of the various crops. Soil quality parameters like pH, organic carbon, total nitrogen, phosphorus and water holding capacity were analysed by following standard procedure.

Results and discussion

Rainfall pattern: Sunflower received 513, 505, 610 and 622 mm rainfall during 1st, 2nd, 3rd and 4th years of experimentation, respectively. During first year, the crop has undergone mild stress during vegetative, bud initiation, flowering and at harvest stages. Moderate stress occurred during vegetative and flowering stages in 2nd

year. Bud initiation and flowering stages experienced moderate stress during 3rd year. In 4th year, crop has undergone severe stress during flowering to grain filling stage. Castor in 5th year received 507 mm rainfall during crop growth period with moderate stress at bud initiation and grain filling stages and severe stress at flowering stage. In 6th year sorghum crop received good and uniformly distributed rainfall of 648 mm.

Direct benefits of soil amendments in producing sunflower: There was a marginal increase in the yields from set rows over broadcasting with incorporation of bentonite alone or in combination with FYM while FYM alone gave significant yield increase with set row application (1040 kg/ha) which is 12% over non-set rows application (984 kg/ha). Application of FYM on an average increased the seed yields of sunflower by 57%, while use of bentonite + FYM gave increased seed yield by 21% over the recommended dose of nutrients @ 50:30:0 NPK kg/ha (678 kg/ha) (Table 1). This is attributed to increased drymatter, leaf area index that resulted due to efficient use of rainfall (Fig. 1). Consequently nitrogen uptake of sunflower was highest with FYM in set rows at different crop growth stages, which resulted in more seed yield of sunflower (Singh and Bansal, 1999 and Singh, 1999) (Fig. 2). Bentonite application during all the years had marginal increase in seed yields of sunflower when applied in set rows, which led to water stagnation.

Residual effects of soil amendments: The residual effects of soil amendments over productivity of castor (GCH-4) and sorghum (CSH-6) in sequence was evaluated during 1997 and 1998, respectively. The bean yield of castor was highest with continuous application of Bentonite followed by Bentonite + FYM @ 10 t/ha for each year. Set row application did not show any improvement in yields over braodcasting on castor. In sorghum, soil amendments on an average registered the seed yield gains by 36% than that of chemical fertilizers (1826 kg/ha). FYM and Bentonite individually had affected positively in set rows while in combination, the positive impact was observed with broadcasting and incorporation (Table 1).

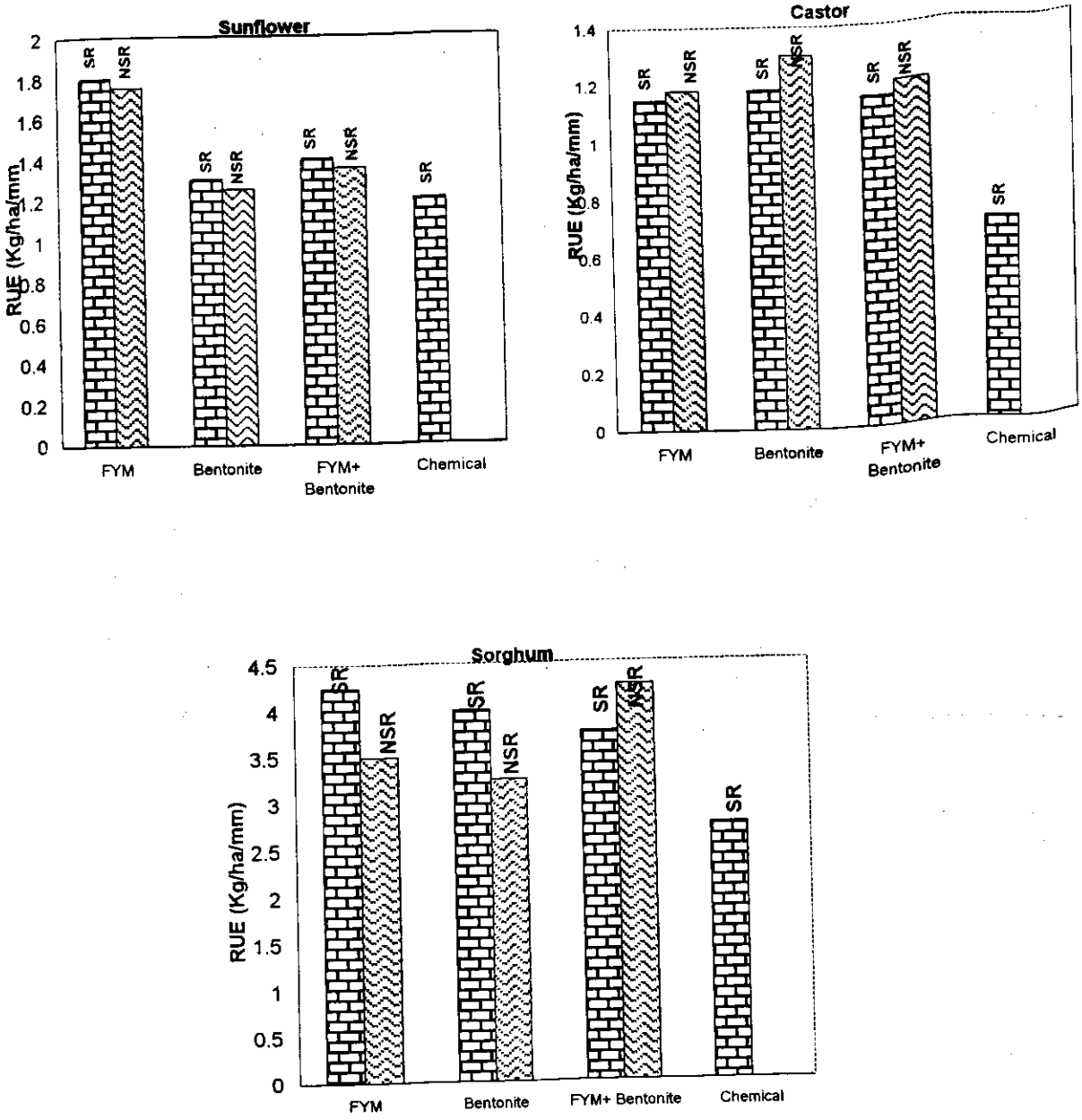
Influence of soil amendments on soil parameters: Continuous application of FYM for consecutive four years period increased organic carbon, N content and water holding capacity of the soil by 5.9, 33 and 8.5% respectively at 0-15 cm soil depth. FYM + Bentonite application recorded highest increase in nitrogen level (66.7%) at 0-15 cm soil depth and also an increase of 8.5% in water holding capacity of the soil (Table 3). Continuous application of nutrients in the form of N:P:K fertilizer alone reduced water holding capacity, organic carbon and N level of soil over base level of nutrients before experiment. Application of nitrogen fertilizers alone to soils had deleterious effect on soil productivity (Anandswarup, 1999). Pattar *et al.* (1999) reported increase in organic carbon nitrogen and phosphorus with FYM application. Continuous application of soil amendments had very little or no effect on P level over initial level, however, the organic carbon and N level showed marginal increase over initial fertility levels.

Table 1 Direct and residual effects of soil amendments on productivity of sunflower, castor and sorghum crops

Treatment	Seed yield (kg/ha)						
	Sunflower					Castor	Sorghum
	1993	1994	1995	1996	Mean	1997	1998
N:P:K (50:30:0) @ kg/ha/year	766	940	558	446	678	378	1826
FYM @ 10 t/ha/year (SR)	1002	1194	1030	932	1040	580	2831
FYM @ 10 t/ha/year (NSR)	1240	1031	915	751	984	596	2335
Bentonite @ 10 t/ha/year (SR)	789	979	638	561	742	580	2671
Bentonite @ 10 t/ha/year (NSR)	864	961	616	534	744	662	2215
FYM + Bentonite @ 10 t/ha/year (SR)	833	1014	801	459	777	567	2452
FYM + Bentonite @ 10 t/ha/year (NSR)	789	1002	790	574	784	618	2803
CD (P=0.05)	50	60	58	53	-	107	185

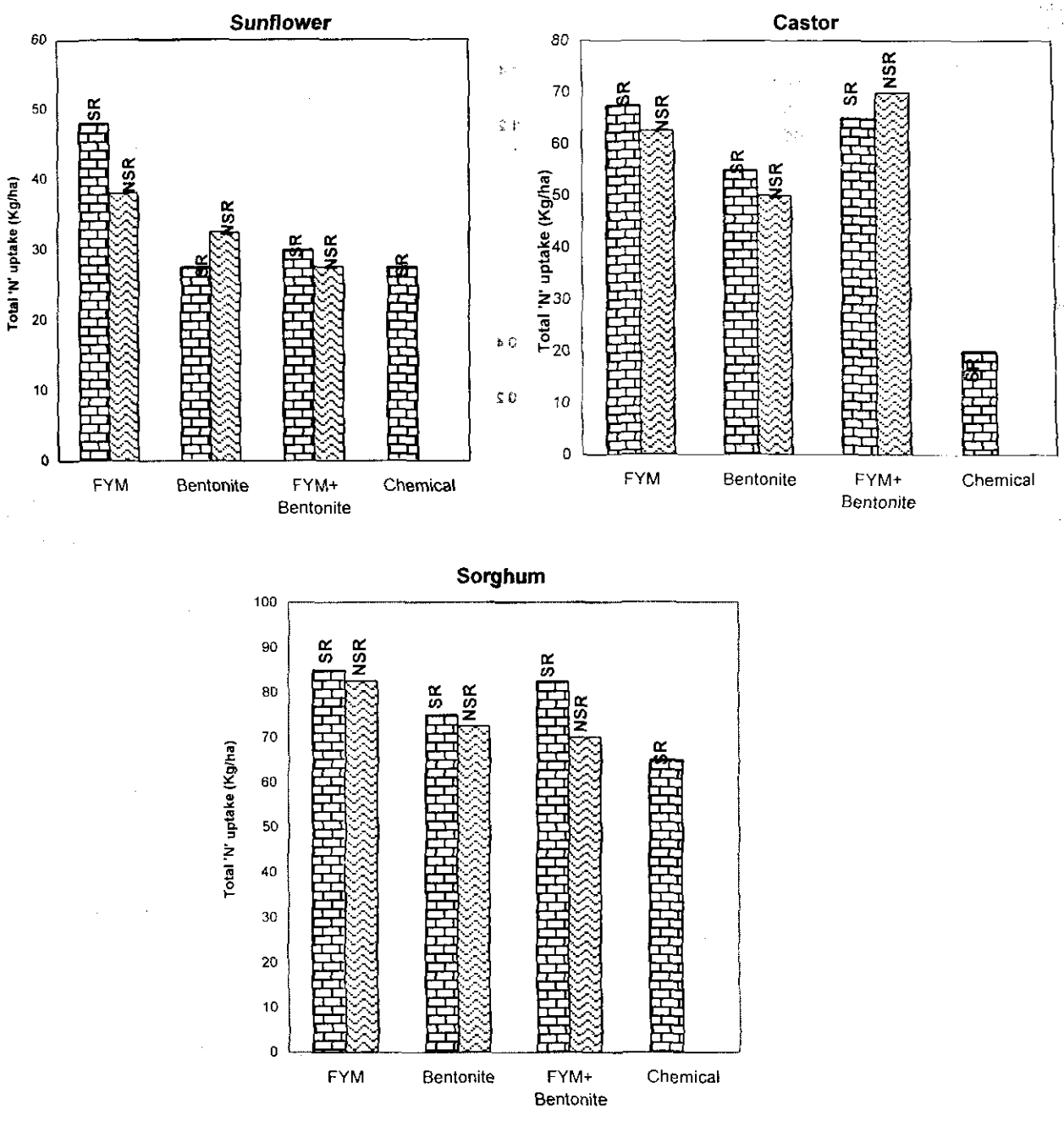
SR : Set rows; NSR = Non-set rows

Fig 1 Effect of sources and methods of application of soil amendaments on Rainfall Use Efficency in rainfed crops.



SR=Set rows, NSR=Non set rows

Fig:2 Effect of sources and methods of application of soil amendments on Nitrogen uptake in rainfed crops.



SR=Set rows, NSR= Non set rows.

Table 2 Residual effect of organic amendments on growth components in sorghum in castor-sorghum rotation and castor in sorghum-castor rotation

Treatment	Drymatter (g/m^2)				Leaf area index			
	Days after sowing				Days after sowing			
	S in C-S		C in C-S		S in C-S		C in C-S	
	30	75	30	75	30	75	30	75
N:P:Kl (50:30:0) @ kg/ha/year	38.0	624.3	27.0	460	0.37	1.44	0.03	0.3
FYM @ 10 t/ha/year (SR)	52.6	835.7	58.8	824	0.71	2.60	0.07	0.3
FYM @ 10 t/ha/year (NSR)	44.6	816.6	60.5	745	0.47	2.58	0.07	0.3
Bentonite @ 10 t/ha/year (SR)	48.3	743.6	44.3	637	0.50	2.56	0.05	0.4
Bentonite @ 10 t/ha/year (NSR)	40.3	670.2	36.9	696	0.42	2.15	0.03	0.3
FYM + Bentonite @ 10 t/ha/year (SR)	46.3	820.1	44.7	635	0.38	2.15	0.04	0.4
FYM + Bentonite @ 10 t/ha/year (NSR)	42.6	888.6	88.0	669	0.39	21.43	0.08	0.3
CD (P=0.05)	21	121	20	170	0.14	0.64	0.03	0.1

SR = Set rows; NSR = Non-set rows

Table 3 Influence of soil amendments on soil parameters in rainfed environment

Treatments	Soil depth (cm)	pH	EC (dS/m)	O.C (%)	Total N (%)	P (mg/kg)	WHC of soil (%)
Initial fertility status (1993)	0-15	6.0	0.06	0.51	0.03	8.2	4.7
	15.30	6.2	0.09	0.53	0.05	4.0	5.5
N:P:K (50:30:0) kg/ha/year	0-15	6.1	0.07	0.50	0.02	7.9	4.8
	15.30	6.3	1.00	0.52	0.03	3.8	5.5
FYM @ 10 t/ha/year (SR)	0-15	6.3	0.08	0.54	0.04	7.9	5.1
	15.30	6.3	0.07	0.56	0.06	4.0	5.8
FYM @ 10 t/ha/year (NSR)	0-15	6.2	0.08	0.53	0.04	8.2	5.0
	15.30	6.3	0.07	0.54	0.06	4.0	5.8
Bentonite @ 10 t/ha/year (SR)	0-15	6.1	0.09	0.48	0.03	7.8	4.7
	15.30	6.2	0.08	0.50	0.04	3.5	5.6
Bentonite @ 10 t/ha/year (NSR)	0-15	6.1	0.10	0.49	0.03	7.8	4.7
	15.30	6.2	0.09	0.50	0.04	3.6	5.6
FYM + Bentonite @ 10 t/ha/year (SR)	0-15	6.25	0.08	0.53	0.04	8.3	5.1
	15.30	6.40	0.07	0.55	0.05	4.0	5.7
FYM + Bentonite @ 10 t/ha/year (NSR)	0-15	6.3	0.08	0.52	0.05	8.4	5.1
	15.30	6.4	0.07	0.55	0.06	4.1	5.8

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J. Oilseeds Res., 23(2) : 239-241 (2006)

Effect of irrigation and integrated nutrient management on seed and oil yield of *rabi* castor, *Ricinus communis* L.

A. Pratap Kumar Reddy, A. Sambasiva Reddy and P. Padmavathi

Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, AP

(Received: June, 2005; Revised: September, 2005; Accepted: December, 2005)

Abstract

A field experiment was conducted during *rabi* season of 2000-01 and 2001-02 to study the effect of irrigation and integrated nutrient management (INM) on yield of *rabi* castor, *Ricinus communis* L. Total seed yield was significantly higher with 0.6 IW/CPE ratio in 2000-01 whereas, during 2001-02, seed yield between 0.6 and 0.8 IW/CPE ratio was at par. INM practices with 75% RDF + 25% N through FYM + *Azospirillum* recorded significantly higher seed yield. Interaction between IW/CPE ratio and INM practices on total seed yield revealed that maximum seed yield was obtained with 0.6 IW/CPE ratio at 75% RDF + 25% N through FYM + *Azospirillum*.

Key words: Irrigation, INM practices, castor, IW/CPE ratio

Introduction

Castor is an important industrial oilseed crop in India fetching a sizeable amount of foreign exchange to the country by virtue of its export rate besides meeting internal demand of various industries such as soaps, paints, varnishes, synthetic detergents and wide range of chemical products. India's share in world's area and production of castor is 68% and 76%, respectively. In Andhra Pradesh, castor occupies an estimated area of 3.93 lakh ha with 1.31 lakh tonnes production with a productivity of 333 kg/ha (Damodaram and Hegde, 2002). Cultivation of castor during *kharif* under rainfed conditions becomes less remunerative. Of late, it is not uncommon to observe the farmers and seed production agencies raising this crop during post-monsoon (*rabi*) season under irrigated conditions for which some of the production technological components like scheduling of irrigation and integrated nutrient management practices are lacking implying the need for generation of production technology for irrigated conditions. Keeping the above points in view, present investigation was carried out.

Material and methods

A field experiment was conducted at Agricultural Research Institute, Rajendranagar, Hyderabad during the *rabi* 2000-01 and 2001-02 under irrigated condition. The soil type was clay in texture, slightly alkaline (pH 8.0), medium in organic carbon (0.6%) low in available nitrogen (183 kg N/ha), medium in available phosphorus (37 kg P_2O_5/ha) and high in available potassium (258 kg K_2O/ha). The experiment was laid out in Split Plot Design with four irrigation schedules (0.4, 0.6, 0.8 and 1.0 IW/CPE ratios) in main plots and eight integrated nutrient management (INM) practices (Control; 75% RDF; 100% RDF; 75% RDF + *Azospirillum*; 75% RDF + 25% N through FYM; 75% RDF + 25% N through FYM + *Azospirillum*; 100% RDF + *Azospirillum*; 100% RDF + 25% N through FYM) in sub-plots with 3 replications. A parshal flume (15 cm throat width) was installed at field outlet to measure the volume of irrigation water. The recommended dose of fertilizer (RDF) was 80 N + 40 P_2O_5 + 30 K_2O kg/ha. Entire dose of phosphorus (single super phosphate) and potash (muriate of potash) and one third of nitrogen (urea) were applied as basal dose and the remaining two third of nitrogen was applied in two equal splits at primary and secondary spike initiation stages. *Azospirillum* was used as seed treatment. The nitrogen, phosphorus and potassium content (%) of FYM were 0.50, 0.41 and 0.52, respectively. The castor hybrid GCH-4 and sown with a spacing of 90 x 60 cm. Depth of irrigation given was 5 cm. Number of irrigations received was 6, 9, 12 and 15 in 0.4, 0.6, 0.8 and 1.0 IW/CPE irrigation schedules, respectively during both the years of study. 100 and 44 mm of rainfall received during cropping season in 2000-01 and 2001-02, respectively. Crop was sown on 10 October and 25 October and harvested on 2 May, 2001 and 3 May, 2002 in 2000-01 and 2001-02, respectively.

Results and discussion

Effect of irrigation: Maximum seed yield of 2158 kg/ha was obtained with 0.6 IW/CPE ratio followed by 0.8 IW/CPE ratio (2017 kg/ha), 1.0 IW/CPE ratio (2015 kg/ha) and 0.4 IW/CPE ratio (1866 kg/ha) in 2000-01. During 2001-02, seed yield between 0.6 IW/CPE ratio (2189 kg/ha) and 0.8 IW/CPE ratio (2193 kg/ha) was on par and significantly superior to 0.4 and 1.0 IW/CPE ratios. During 2000-01 seed yield obtained with 0.6 IW/CPE ratio was higher by 15.6, 2.4 and 7.1 per cent over 0.4, 0.8 and 1.0 IW/CPE ratios, respectively. Higher seed yield with 0.6

and 0.81 IW/CPE ratio might be due to increased availability of nutrients under optimum soil moisture. Sudhakar and Rao (1998), Nagabhushanam (2002) and Kiran (2003) reported higher yield under medium soil moisture regime compared to wet and dry regimes.

In the present study, IW/CPE ratios did not influence the oil content in both the years. The findings of Sudha Rani (2001) and Nagabhushanam (2002) corroborate with these observations. Though oil content did not vary due to IW/CPE ratios, significantly higher oil yield with 0.6 IW/CPE ratio was due to higher seed yield (Table 1).

Effect of INM: Seed yield (2490 kg./ha in 2000-01 and 2522 kg/ha in 2001-02) obtained with 75% RDF + 25% N through FYM + *Azospirillum* (T_6) was significantly higher compared to rest of the treatments in both the years. Seed yield obtained with 100% RDF (T_3) was significantly higher compared to T_1, T_2, T_4 and T_5 in both the years. Lowest seed yield of 1228 kg/ha in 2000-01 and 1297 kg/ha in 2001-02 was obtained with control (T_1). Seed yield obtained with T_6 was higher by 103, 55, 12, 25, 24, 6 and 5 per cent over T_1, T_2, T_3, T_4, T_5, T_7 and T_8, respectively during 2000-01. During 2001-02, the corresponding values were 95, 51, 9, 20, 7 and 6 per cent (Table 1).

The INM practices exerted significantly influence on the oil content of castor. In general, oil content was higher with 100% RDF + *Azospirillum* (T_7) during both the years. Oil yield was higher with 75% RDF + 25% N through FYM + *Azospirillum* (T_6) but was comparable with T_7 and T_8 in 2000-01. Higher oil yield was primarily due to higher seed yield. Similar results were reported by Mathukia and Modhwadia (1995), Raghavaiah (1999) and Sesha Saila Sree (2001).

Interaction effect: Interaction between IW/CPE ratios and INM practices was significant in both the years (Table 2). Seed yield obtained with T_6 was higher compared to rest of the treatments at all IW/CPE ratios in both the years but it was on par with T_8 at 0.8 IW/CPE ratio in 2000-01 and T_7 and T_8 at 0.4 IW/CPE ratio in 2001-02. Seed yield with control (T_1) was significantly lower compared to rest of the treatments at all IW/CPE ratios in both the years.

Interaction between IW/CPE ratios and INM practices in respect of oil yield was significant during 2000-01 (Table 2). Maximum oil yield was obtained with T_6 at 0.4, 0.6 and 0.8 IW/CPE ratios but it was at par with T_8 at 0.6 and 0.8 IW.CPE ratios. At 1.0 IW.CPE ratio, oil yield obtained between T_7 and T_8 was comparable and both the treatments were significantly superior to rest of the treatments. Oil yield obtained with T_1 was significantly lower compared to rest of the treatments at all IW/CPE ratios.

Table 1 Seed yield, oil content and oil yield of castor as influenced by IW/CPE ratios and INM practices

Treatment	Seed yield (kg/ha)		Oil content (%)		Oil yield (kg/ha)	
	2000-01	2001-02	2000-01	2001-02	2000-01	2001-02
IW/CPE ratio						
0.4	1866	1931	51.2	49.5	955	956
0.6	2158	2189	50.5	49.8	1090	1090
0.8	2106	2194	50.5	48.6	1065	1066
1.0	2015	2057	50.2	49.2	1012	1012
SEm±	12	13	0.2	0.3	2	3
CD (P=0.05)	42	46	NS	NS	8	10
INM practices						
T_1 : Control	1228	1297	49.7	49.9	611	647
T_2 : 75% RDF	1609	1666	50.2	50.0	808	833
T_3 : 100% RDF	2228	2319	51.1	48.9	1139	1134
T_4 : 75% RDF + *Azospirillum*	1993	2095	50.3	48.5	1003	1017
T_5 : 75% RDF + 25% N through FYM	2013	2098	50.4	48.4	1015	1015
T_6 : 75% RDF + 25% N through FYM + *Azospirillum*	2490	2522	49.3	48.5	1228	1223
T_7 : 100% RDF + *Azospirillum*	2354	2381	51.7	50.4	1216	1199
T_8 : 100% RDF + 25% N through FYM	2375	2364	51.3	49.9	1219	1180
SEm±	18	14	0.7	0.3	10	4
CD (P=0.05)	51	41	1.8	0.8	29	10

Table 2 Interaction effect of IW/CPE ratios and INM practices on total seed and oil yield of castor (kg/ha)

Treatment	Seed yield (kg/ha)								Oil yield (kg/ha)			
	2000-01				2001-02				2000-01			
INM practices	IW/CPE ratio				IW/CPE ratio				IW/CPE ratio			
	0.4	0.6	0.8	1.0	0.4	0.6	0.8	1.0	0.4	0.6	0.8	1.0
T_1 : Control	1101	1316	1308	1190	1125	1376	1400	1283	541	656	655	592
T_2 : 75% RDF	1449	1704	1671	1612	1486	1787	1709	1683	724	863	839	807
T_3 : 100% RDF	2092	2287	2332	2201	2113	2485	2418	2262	1063	1168	1206	1117
T_4 : 75% RDF + *Azospirillum*	1709	2208	2027	2030	1862	2259	2155	2105	861	1113	1021	1017
T_5 : 75% RDF + 25% N through FYM	1839	2158	2091	1962	1981	2188	2206	2019	920	1102	1054	986
T_6 : 75% RDF + 25% N through FYM + *Azospirillum*	2360	2610	2537	2454	2333	2659	2654	2442	1220	1340	1285	1069
T_7 : 100% RDF + *Azospirillum*	2197	2484	2413	2319	2261	2415	2512	2333	1137	1275	1226	1226
T_8 : 100% RDF + 25% N through FYM	2182	2497	2473	2344	2287	2345	2493	2330	1128	1297	1262	1195
		SEm±	CD (P=0.05)			SEm±	CD (P=0.05)			SEm±	CD (P=0.05)	
Between INM practices at the same/different IW/CPE ratio		36	102			29	82			20	57	
Between IW/CPE ratios at the same of different INM practices		36	101			30	85			19	54	

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J. Oilseeds Res., 23(2) : 242-246 (2006)

Response of niger, *Guizotia abyssinica* (L.f) Coss in terms of growth analysis, yield attributes and seed yield to integrated nutrient management in Madhya Pradesh

M.R. Deshmukh, R.S. Sharma[1], A.K. Pandey[2] and S.S. Duhoon

Project Coordinating Unit (Sesame & Niger), J.N. Krishi Vishwa Vidyalaya, Jabalpur-482 004, MP

(Received: December, 2005; Revised: April, 2006; Accepted: June, 2006)

Abstract

A field experiment was conducted on niger, *Guizotia abyssinica* (L.f.) Cass c.v. Ootakmand during *kharif* seasons of 2001 and 2002 on clay loam soil of Jabalpur (Madhya Pradesh) to minimize the use of N-fertilizers through integrated nutrient supply system for sustainable productivity. Results revealed that application of 100% N through Urea and FYM applied either alone or in combination with PSB or 50% N through Urea or FYM in combination with PSB/*Azospirillum*/*Azotobacter* had significantly higher LAI, TDM, CGR, RGR and NAR values with increased seed yield of niger over control. Seed yield was maximum with 50% N through Urea + 50% N through FYM mainly due to superiority in above growth analytical parameters and yield attributes viz. captitula/plant and seeds/captitula. Use of bio-fertilizers, *Azospirillum* and *Azotobacter* either alone or in combinations were comparable to 50% N applied through manures or fertilizers with regard to growth analytical parameters and seed yields. The application of bio-fertilizers alone or in combinations along with fertilizer or FYM equivalent to 50 % N further increased the seed yields.

Key words: Integrated nutrient management, biofertilizer, crop growth rate (CGR), relative crop growth rate (RGR)

Introduction

Niger contributes to about 3% of Indian oilseed production. It is generally grown on marginal and sub-marginal lands, mainly in tribal pockets with the use of minimum agro inputs, particularly fertilizers leading to very low productivity (Sharma, 1993). Nutrient stress is the most important factor responsible for its low productivity. Several workers have reported positive response of niger to fertilizers (Mamatha *et al.*, 1993), organic manures (Ram *et al.*, 1992) and biofertilizers (Hegde, 1998). But these results are not consistent in field conditions under varying agroclimatic conditions. Poor farmers associated with its cultivation are unable to afford desirable quantity of fertilizers to enhance the productivity. Hence, it is imperative to evaluate the integrated use of organic and biological sources of plant nutrition with fertilizers for increasing the productivity in a sustainable manners. Lack of adequate information on these aspects prompted the present study to assess the effect of integrated use of organic, inorganic and biofertilizers on the performance of niger.

Material and methods

Field experiments were carried out on niger at the research farm, Project Coordinating Unit (Sesame and Niger), J.N. Krishi Vishwa Vidyalaya, Jabalpur (MP) during *kharif*, 2001 and 2002. The soil of experimental field was clay loam in texture, neutral in reaction (pH 7.2) and analyzing low in available N (220 kg/ha), P (7.2 kg/ha), S (6.8 kg/ha); and medium in available K (211 kg/ha) contents with normal electrical conductivity (0.35 dS/m^2). Eighteen treatments (Table 1 and 2) were laid out in Randomized Block Design with three replications. Crop variety Ootakmand was sown on 24 July, 2001 and 4 August, 2002 using 5 kg seed/ha in rows 30 cm apart.

The Farm yard manure (FYM) used, contained 0.6% N, 0.2% P_2O_5 and 0.80% K_2O on dry weight basis. Seeds were inoculated with *Azotobacter* and *Azospirillum* at the time of sowing, while phosphorus solubilising bacteria (PSB) was applied @ 600 g/ha by mixing with 50 kg FYM/ha in the rows at the time of sowing. FYM was applied as per treatments before sowing and mixed well in the soil. Half the quantity of N along with full dose of P and K were applied as basal dose, while rest half N was top dressed one month after sowing. The recommended N dose was 40 kg/ha and was applied through urea as per treatment, whereas a uniform dose of 20 kg P_2O_5/ha + 20 kg K_2O/ha was applied through single super phosphate and muriate of potash, respectively in all plots. The

[1] Professor & Head, Department of Agronomy, J.N..Krishi Vishwa Vidyalaya, Jabalpur, M.P.

[2] Reader, Department of Botany (Post-Graduate Studies & Research), RDVV, Jabalpur, M.P.

observations on leaf area and total drymatter (TDM) accumulation were recorded at 30, 60, and 90 days after sowing (DAS). The leaf area was recorded by Automatic leaf area meter (LI 3000). Then leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) at different growth stages were estimated by using the data on leaf area and DM production as per formula suggested by Watson (1952). The observations on yield attributing characters and seed yield were recorded.

Table 1 Effect of various nutrient management on growth analytical parameters (CGR, RGR, NAR) of niger (Mean data for the years, 2001 and 2002)

Nutrient management	Crop growth rate ($g/m^2/day$)			Relative growth rate (g/g/day)			Net assimilation rate (g/m^2 leaf area/day)		
	30-60 DAS	60-90 DAS	90 DAS (Maturity)	30-60 DAS	60-90 DAS	90 DAS (Maturity)	30-60 DAS	60-90 DAS	90 DAS (Maturity)
Control	9.27	9.26	17.49	0.048	0.024	0.018	3.635	3.147	3.56
100% N (U)	14.31	11.34	33.88	0.050	0.014	0.022	4.196	5.165	4.45
100% N (FYM)	14.06	11.17	26.99	0.050	0.026	0.021	4.194	4.930	4.85
100% N (FYM) + PSB	14.70	11.76	34.93	0.044	0.015	0.026	4.209	5.958	5.58
100% N (U)+PSB	14.76	11.57	33.97	0.050	0.015	0.022	4.219	5.504	5.03
50% N (FYM) + PSB	13.79	11.02	24.84	0.051	0.016	0.021	4.159	4.654	4.84
50% N (FYM)+ *Azospirillum*	13.10	10.47	23.50	0.050	0.017	0.021	4.110	4.474	4.71
50% N (FYM) + *Azotobacter*	12.86	10.40	25.15	0.050	0.017	0.032	4.014	3.949	4.57
50% N (FYM) + 50 N (U)	14.53	11.80	36.08	0.042	0.014	0.027	4.219	6.429	5.65
50% N (U) + PSB	12.36	10.17	24.33	0.051	0.017	0.020	3.903	3.843	4.46
50% N (U) + *Azospirillum*	12.80	10.26	25.00	0.051	0.011	0.020	3.929	3.884	4.50
50% N (U) + *Azotobacter*	12.91	10.51	25.04	0.050	0.017	0.020	4.103	4.239	4.64
PSB	10.20	9.34	20.91	0.052	0.020	0.019	3.665	3.285	3.93
Azospirillum	11.01	9.92	21.95	0.051	0.021	0.020	3.758	3.412	4.24
Azotobacter	10.64	9.76	21.92	0.050	0.021	0.020	3.729	3.318	4.20
Azospirillum + PSB	12.14	10.12	23.49	0.051	0.018	0.020	3.877	3.726	4.38
Azotobacter + PSB	11.53	10.01	22.29	0.270	0.021	0.020	3.865	3.604	4.29
Azotobacter + *Azospirillum* + PSB	11.73	10.15	24.42	0.051	0.018	0.020	3.892	3.757	4.38
SEm±	1.14	0.22	3.06	0.004	0.004	0.003	0.587	0.450	0.230
CD (P=0.05)	3.98	1.32	8.77	NS	NS	NS	NS	NS	NS

U = Urea; FYM = Farm yard manure; AZOT = *Azotobacter*; AZOS = *Azospirillum*; PSB =Phosphorus solubilizing bacteria; DAS = Days after sowing

Table 2 Effect of nutrient management on yield attributes and seed yield of niger

Nutrient management	No. of capitula/plant			No. of seeds/capitulum			1000-seed weight (g)			Seed yield (kg/ha)		
	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean
Control	57.3	47.7	52.5	15.9	17.9	16.9	3.1	3.7	3.4	331	408	369
100 %N (U)	80.5	91.7	86.1	22.9	24.5	23.7	3.9	4.2	4.0	489	537	513
100 %N (FM)	78.3	89.7	83.8	20.0	23.7	22.8	3.9	4.2	4.0	471	523	497
100 %N (FYM) + PSB	85.3	94.7	90.0	24.4	24.6	24.5	4.2	4.3	4.2	511	554	532
100 %N (FYM) + PSB	83.2	92.5	87.8	23.2	24.9	24.0	3.9	4.2	4.0	503	552	527
50 %N (FYM) + PSB	75.4	85.7	80.5	20.9	23.7	22.3	3.8	4.1	3.9	459	519	489
50 %N (FYM) + *Azospirillum*	73.4	83.8	78.6	20.5	23.2	21.8	3.7	4.1	3.9	451	501	476
50 %N (FYM) + *Azotobacter*	71.7	74.5	73.1	19.9	21.9	20.9	3.7	4.0	3.8	441	495	468
50 %N (FYM) + 50 N (U)	87.0	98.7	92.8	25.0	24.4	24.7	4.3	4.3	4.3	542	555	549
50 %N (U) + PSB	70.8	70.1	70.4	19.5	21.7	20.6	3.7	4.1	3.9	432	487	459
50 %N (U) + *Azospirillum*	71.6	72.2	71.9	19.7	21.8	20.7	3.7	4.0	2.5	438	494	466
50 %N (U) + *Azotobacter*	72.9	78.6	75.7	20.0	23.0	21.5	3.7	4.1	3.9	442	497	469
PSB	65.3	57.7	61.5	16.3	19.1	17.7	3.4	3.8	3.6	345	423	384
Azospirillum	66.8	59.9	63.3	17.7	20.7	19.2	3.6	3.9	3.7	380	445	412
Azotobacter	65.7	58.6	62.1	16.6	19.7	18.1	3.5	3.9	3.7	375	425	400
Azospirillum + PSB	67.9	67.8	67.8	19.0	21.0	20.0	3.7	4.0	3.8	389	452	420
Azotobacter + PSB	67.4	63.7	65.5	17.8	20.8	19.3	3.6	3.9	3.7	387	436	412
Azotobacter + *Azospirillum* + PSB	70.0	68.3	69.1	19.1	21.2	20.1	3.7	4.0	3.8	403	468	435
SEm±	3.0	3.9	3.3	1.6	1.6	1.4	0.2	0.1	0.2	20	16	31
CD (P=0.05)	8.8	11.4	9.5	4.7	4.6	4.2	NS	NS	NS	58	46	84

U = Urea; FYM = Farm yard manure; AZOT = *Azotobacter*; AZOS = *Azospirillum*; PSB =Phosphorus solubilizing bacteria; DAS = Days after sowing

Results and discussion

Growth analysis: The LAI increased up to 60 DAS and thereafter, it declined during both years in all the treatments (Fig. 1). The photosynthetic area (LAI) at different growth stages increased significantly with 100% N applied either alone or in combination with both organic and inorganic sources over control. Application of biofertilizers (*Azospirillum* or *Azotobacter* or PSB) along with 50% N through inorganic or organic sources of N significantly increased LAI over control, but values did not increase significantly at different growth stages.

The TDM/m^2 increased with the advancement in growth stages upto maturity stage with the rapid rate of increase between 90 DAS and harvest stages in all treatments during both years (Fig. 2). The TDM/m^2 was significantly higher with the application of 100% N through urea or FYM either alone or in combination of each with PSB, or 50% N through urea and FYM over control due to greater accumulation of photosynthates. Application of N through FYM alone produced lesser TDM/m^2 than Urea alone at 100% level of N. The treatment FYM + PSB proved better than Urea + PSB in this regard. Application of 50% N through urea + 50% N through FYM proved the best with regard to production of TDM. All plots receiving biofertilizer inoculation alone or in combination produced significantly higher TDM/m^2 than control during both years at advanced growth stages probably due to increased nitrogen availability to plants. Similar results were reported by Kachpur and Radder (1983 a; b).

The CGR values also relatively increased with the advancement in growth stages up to maturity with a slight reduction during 60 to 90 DAS stages, because of rapid rate of drymatter accumulation in plants during advanced growth stages. Application of inorganic and organic sources of N with biofertilizers had higher CGR values over control. The CGR at different stages increased significantly with 100% N through urea as well as FYM alone or in combination with PSB and combination of 50% N through Urea and FYM over control.

The RGR and NAR values were maximum during early growth stage (30 to 60 DAS), which reduced with the advancement in the growth stages. The accumulated photosynthates and food materials of plants are normally utilized by the plants for their phasic development *viz* increase in plant height, branching, leaves, flowering, pod formation and grain filling etc. Consequently, the rate of DM accumulation over each unit of DM already present is reduced. The NAR also gradually reduced during advancement in growth stages up to 90 DAS in both years due to reduced LAI and RGR. The mean data on growth parameters (CGR, RGR and NAR) were lower in control than remaining plots receiving N application through different sources *viz.*, inorganic (urea), organic (FYM) and biofertilizer (PSB/*Azotobacter*/*Azospirillum*) applied either alone or in combination. These values were maximum with 100% N applied through different sources. These results corroborate with the findings of Kachpur and Radder (1983 a; b).

Yield attributes: The yield contributing characters *viz.* capitule/plant and seeds/capitula significantly varied due to different rates and sources of N application in both the years, but 1000-seed weight did not differ with them (Table 2). These characters were significantly superior under the treatments receiving 100% N through inorganic (urea) or organic (FYM) sources of N than other treatments including 50% N through different sources or bacterial inoculation through PSB/*Azotobacter*/*Azospirillum* alone or in combinations and control. Different yield attributing characters *viz.*, capitulae/plant and seeds/capitulum were significantly superior with the treatments receiving 100% recommended N through different sources than other treatments consisting with 50% N through different sources, bacterial inoculation through PSB/*Azotobacter*/*Azospirillum* either alone or in combination and control. Application of 50% N through urea + 50% N through FYM was superior pertaining to these yield attributes closely followed by 100% N through urea or FYM alone as well as in combination with PSB. Application of 50% N through urea/FYM alone or along with different bio-inoculants produced inferior yield attributing characters than 100% level of N. Application of PSB/*Azotobacter*/*Azospirillum* either alone or in combination of two as well as all the three bio-inoculants produced superior yield attributes than control, but the differences were not significant with PSB alone. Though bacterial inoculation proved inferior to 50% N through FYM/urea + bacterial inoculation, the differences were not much, particularly when 2 or 3 bio-fertilizers were used together. As a whole, application of N through any of the sources remarkably improved the yield attributing parameters over control.

Seed yield: Application of recommended N through different sources gave significantly higher seed yield than lower dose of N as well as various bacterial inoculations applied either alone or in various combinations. At 100% N level, integrated use of half N through urea and remaining half N through FYM consistently produced higher seed yield in both years than application of full N through urea/FYM either alone or in combination with PSB. Inoculation of PSB with both urea fertilizer and FYM proved promising than their sole application. Integrated use of FYM and PSB proved marginally better than urea + PSB for seed yield at both levels of N (100 and 50%) application. Yield attributes of crop were better with the application of N through FYM than that of through urea because of adequate supply of N at a steady rate to the

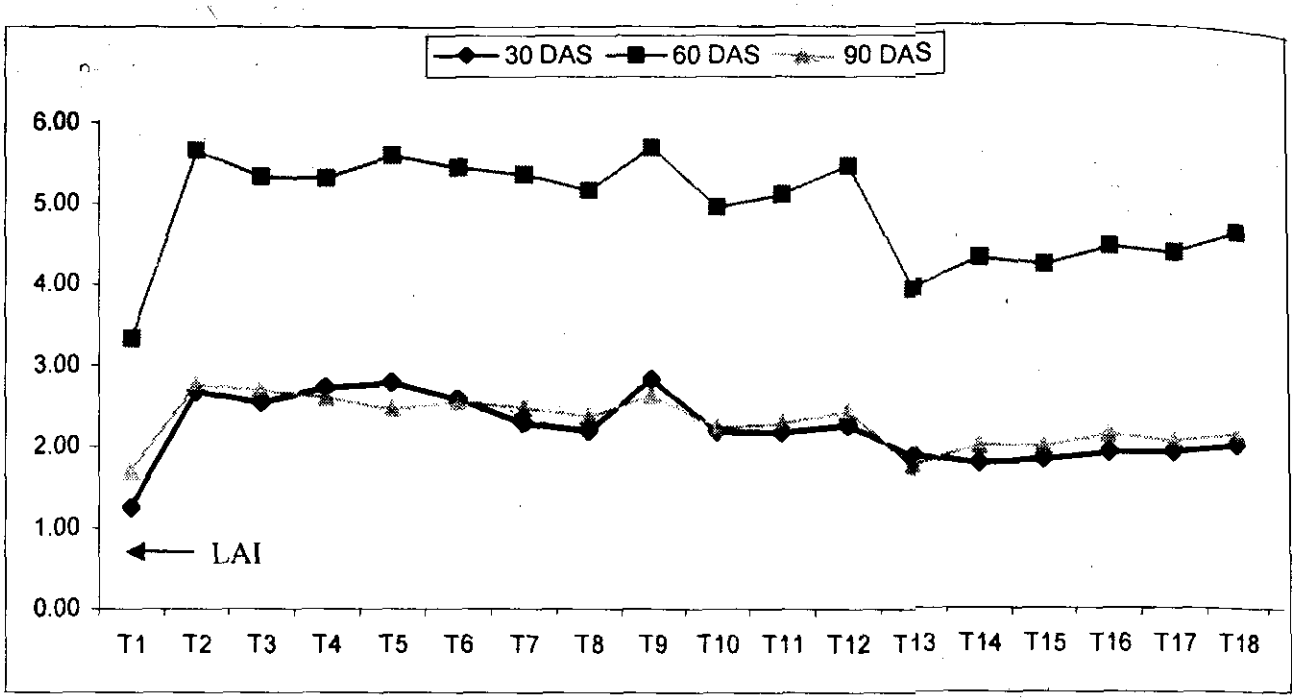

Figure 1. Leaf area index of niger at different growth stages under various nutrient management.

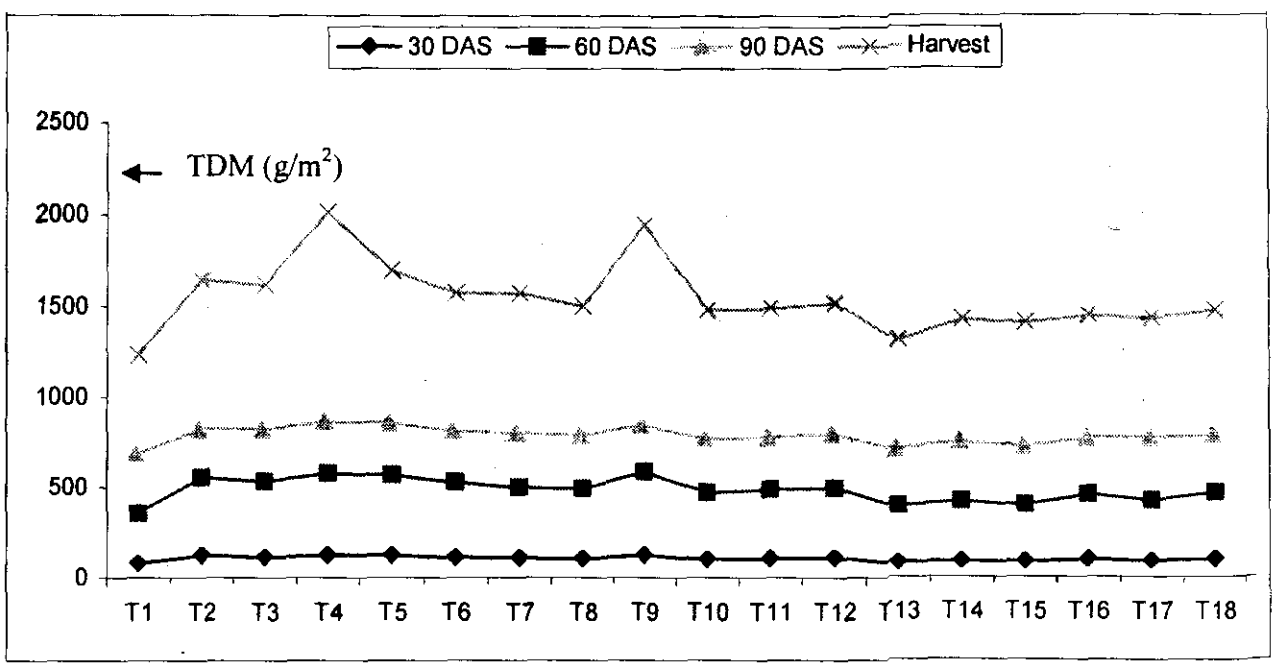

Figure 2. Total dry matter (TDM)/M^2 of niger at various growth stages under various nutrient management.

crop plants. But N applied through urea probably leached down and thus proved less effective than FYM. Addition of PSB with urea or FYM probably improved the availability both applied and native P and thus, produced higher seed yields. These results are in conformity with the findings of Thakuria and Gogoi (1992), Paul *et al.* (1993), Jain *et al.* (1999) and Deshmukh *et al.* (2002). All of the bio-fertilizers applied either alone or in combination with each other produced consistently higher seed yields than control. The combined use of all the bio-inoculants *viz.*, PSB, *Azotobacter* and *Azospirillum* was at par to 50% N applied through urea or FYM each alone or in combination of PSB in terms of seed yields. Among different bacterial cultures, the seed yield was minimum under PSB, which was comparable to control.

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J. Oilseeds Res., **23**(2) : 247-251 (2006)

Genetic studies on leaf chlorophyll content in groundnut, *Arachis hypogaea* L. in terms of SPAD chlorophyll meter reading

M. Babitha, R.P. Vasanthi and P.V. Reddy

Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Tirupati-517 501, AP

(Received: February, 2005; Revised: September, 2005; Accepted: December, 2005)

Abstract

To stabilize groundnut productivity grown rainfed, it is necessary to develop drought resistant groundnut varieties. Earlier, the drought resistance-breeding programme largely concentrated on selection based on higher yield under drought conditions. Later on, drought resistance was found to be associated with a number of physiological traits, of which leaf 'N' status is closely correlated one. Leaf 'N' status is reflected in leaf chlorophyll content. Leaf chlorophyll content in a relative manner can be obtained through SPAD chlorophyll meter reading (SCMR). In the present study, an attempt has been made to understand the nature of inheritance of SCMR through study of F_2 population of six cross combinations. Thus, from studies on the distribution in F_2 generation and genetic variability and heritability studies, it could be inferred that the trait, leaf chlorophyll content (SCMR) might be under the influence of non-additive gene action. Selection for SCMR would be more effective in later segregating generations when the confusing effects of dominance and epistasis would disappear.

Key words: Groundnut, leaf chlorophyll content, inheritance and SPAD chlorophyll meter reading

Introduction

Groundnut is the major oilseed as well as food crop of India. It is mainly grown as a rainfed crop in drylands during *kharif* season. During *kharif*, the pod yield of the rainfed crop varies from 500 to 1100 kg/ha depending upon the distribution of the rainfall. The major constraint in this situation is moisture stress at different stages of crop growth. Thus, to stabilize the yield under rainfed situation, the solution lies in development of drought tolerant groundnut genotypes. Passioura (1977) developed an useful framework for examining crop yield performance under water limited conditions and it has been successfully used to analyse yield variation due to water stress in many crops i.e., pod yield = water transpired (T) x WUE (W) x harvest index (HI). Water use efficiency can be indirectly measured through estimation of CID in leaf (△) and specific leaf area (SL"A). Rao *et al.* (2001) observed significant correlations between SPAD chlorophyll meter reading (SCMR), SLA and specific leaf nitrogen (SLA) in peanut and suggested that SCMR could be used as a rapid, low-cost, non-destructive technique to screen large breeding populations for SLA or SLN. A strong inverse relationship observed between SLA and SLN indicated that SLN might be the cause of linkage between SCMR and SLA in peanut. This was evident from the strong positive relationship between SCMR and SLN. These studies indicated that SCMR is a potential physiological trait to employ as a surrogate for TE in peanut. Thus, a quick determination of SLN through SCMR could reflect the intrinsic mesophyll efficiency and hence can effectively estimate TE in peanut. A rapid assessment of WUE through SCMR was facilitated by the use of a hand held portable SPAD chlorophyll meter, which is useful for screening large segregating populations (Rao *et al.*, 2001; Bindu Madhava *et al.*, 2003). Significant negative correlation was observed between SCMR and SLA in parents while a little decrease in the extent of negative relationship between SCMR and SLA was observed in F_2 populations in a study involving eight parents and F_2 populations derived from 28 single crosses (Venkateswarlu, 2005). Thus, there is scope for using SCMR as selection criterion for WUE even in segregating populations, as the correlations did not change in segregating populations. Many of the morphological traits are reported as qualitatively inherited in peanut (Wynne and Coffelt, 1982). Some of the traits such as branching pattern, leaflet size (length and breadth), fruit length, and main axis height were reported as quantitative traits (Wynne, 1975; Mouli *et al.*, 1984). So farm, very little work has been done on the inheritance of physiological traits like leaf chlorophyll content in groundnut. Thus, this study was undertaken to know the mode of inheritance to formulate efficient breeding programmes for selection for WUE.

Material and methods

The experimental material consisted of F_2 populations of six groundnut crosses *viz.*, TCGS-320 x Jal 30, Tirupati-4 x Jal 30, K-134 x Jal 30, VRI-2 x Jal 30, TCGS 29 x Jal 30 and JL 24 x Jal 30. The male parent, Jal 30 is an advanced breeding line with high SCMR while the female

parents were all high yielding varieties with moderate to low SCMR. F_2 populations and parents were grown in a Randomized Block Design with three replications at the Regional Agricultural Research Station, Tirupati during *kharif*, 2003. F_2 population of each cross was sown in a plot of 3 rows of 5 metres length while parents were sown in a single row of 5 metres length adopting a spacing of 30 x 10 cm. Five F_1 plants raised separately in each cross were used to record SCMR. SCMR of individual plants was taken on leaflets of third leaf individual plants of F_2 population were grouped into different classes taking a class interval of two for SCMR. Skewness and Kurtosis of F_2 distributions were calculated as per Snedecor and Cochran (1980) to check departure from normality.

Simple estimates of the co-efficient of skewness (g_1) and kurtosis (b_1) and of the amount of kurtosis (g_2) were computed for each F_2 population as follows:

$g_1 = m_3/(m_2\sqrt{m_2})$; $b_2 = m_4/m_2^2$; $g_2 = b_2-3$

where $m_3 = \Sigma(X-X)^3/n$; $m_2 = \Sigma(X-X)^2/n$;

$m_4=h_4-4h_1h_3+6h_1^2h_2-3h_1^4$; $h_1=\Sigma fU/n$; $h_2=\Sigma fU^2/n$;

$h_3 = \Sigma fU^3/n$; $h4 = \Sigma fU^4/n$

Results and discussion

SCMR in F_1s was intermediate in crosses i.e., TCGS 320 x Jal 30 and TCGS 29 x Jal 30. In the other cross combinations, it was nearer to the high SCMR parental genotype, Jal 30 (Table 1). From the expression of the trait in F_1s, it appears to be governed by genes that show partial dominance and dominance respectively. F_2 distributions for SCMR of the six crosses were all unimodal and continuous (Fig. 1). According to Allard (1960), continuous variation of a trait can be caused by low heritability or by a large number of genes. The SCMR values of the parental genotypes, TCGS 320, Tirupati-4, K-134, VRI-2, TCGS-29, JL-24 and Jal 30 were 40, 40, 42, 37, 38, 42 and 45, respectively (Table 1). The SCMR values of the parental cultivars used were found to be consistent across seasons and hence environmental variation could be presumed negligible. A significant positive relationship ($r=0.66$, $P<0.05$, $n=18$) between SCMR measured at 55 and 85 DAS implied maintenance of genotypic ranking for SCMR and hence a low G x E interaction for this trait (Bindu Madhava et al., 2003). In the present study also heritability was found to be high in F_2 generation of all the crosses (Table 3). Thus, the second hypothesis is more likely to be correct i.e., SCMR may be determined by many genes with cumulative effects.

Distribution shapes were different in F_2 generation of different crosses. F_2 distribution in the cross, TCGS 29 x Jal 30 showed significant positive skewness while skewness in the remaining crosses was not significant (Table 2 and 3). Significant negative kurtosis was observed in F_2 distribution of the cross, VRI-2 x Jal 30 while kurtosis was not significant in the other crosses (Table 3). The variability in skewness and kurtosis observed in F_2 populations derived from different parental combinations could be due to different allelic composition of the parents and unequal allelic frequencies. First, F_2 population from such a pair of parents with unequal allelic frequencies would present asymmetrical or 'J' shaped distributions, assuming additivity in all loci, no epistasis, and independent factors. Second, non-additive relationships (dominance and/or epistasis) may exist within and/or among same loci. Such relationships can induce asymmetry and kurtosis in F_2 populations. The extent of genotypic coefficient of variability (GCV) was low with GAM below 20% in F_2 generation of the five crosses in the present study (Table 4). Thus, the SCMR might be more under the influence of non-additive genes and hence selection could be practiced in later generations. Sandhu and Khehra (1983) found significant epistatic component of variance for leaflet length and leaflet breadth in groundnut. In a study of 30 cross combinations made in LxT fashion in F_1 generation, Vasanthi et al. (2004) observed significant non-additive gene action for SCMR.

In F_2 populations, TCGS 320 x Jal 30, Tirupati-4 x Jal 30 and JL 24 x Jal 30, the distribution was almost normal with no significant values of skewness and kurtosis. In the crosses i.e., Tirupati-4 x Jal 30, VRI-2 x Jal 30, JL 24 x Jal 30 and TCGS 29 x Jal 30, the parental genotypes were more diverse. The distributions showed wide variation and the distributions also approached normality (Fig. 1). In the aforesaid crosses, all the female parents were spanish bunch types with no virginia bunch background in their pedigree. Jal 30 is a virginia bunch line derived from ICGS 76 x CSMG 84-1 in which both the parents are virginia bunch lines. In spite of the virginia background of K-134, in the cross K-134 x Jal 30, significant negative skewness was observed which could be due to unfavourable inter-allelic interactions. In the crosses, TCGS 29 x Jal 30 and VRI-2 x Jal 30, significant positive skewness and significant positive kurtosis respectively were observed which could be due to favourable allelic interactions (Fig. 1 and Table 3).

Table 1 SCMR of parents and F_1s

Parents/F_1s	SCMR
TCGS 320	40
Tirupati-4	40
K-134	42
VRI 2	37
TCGS 29	38
JL 24	42
Jal 30	45
TCGS 320 x Jal 30	43
Tirupati-4 x Jal 30	44
K-134 x Jal 30	45
VRI 2 x Jal 30	44
TCGS 29 x Jal 30	42
JL 24 x Jal 30	44

Table 2 Frequency distribution for SCMR in F_2 population of six crosses of groundnut

Class interval	TCGS 320 x Jal 30	Tirupati-4 x Jal 30	K-134 x Jal 30	Vri-2 x Jal 30	TCGS-29 x Jal 30	JL 24 x Jal 30
28-30	0	0	0	0	2	0
30-32	5	8	3	14	15	3
32-34	10	16	8	38	33	7
34-36	30	45	20	34	57	13
36-38	70	84	49	73	57	37
38-40	91	87	79	75	49	72
40-42	75	58	93	58	49	88
42-44	62	26	82	31	29	71
44-46	17	9	34	22	12	34
46-48	8	5	9	0	0	16
48-50	0	0	2	2	3	7
50-52	0	0	0	0	1	1

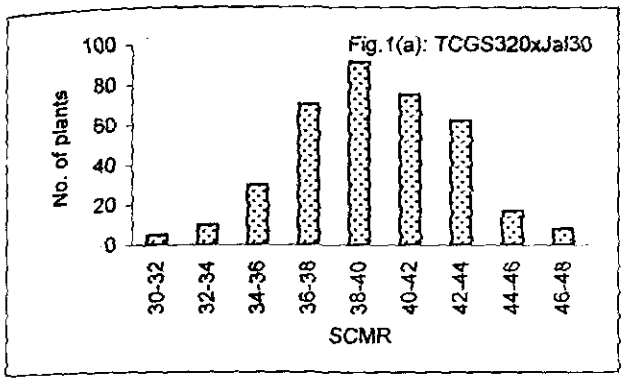
Table 3 Results of skewness and kurtosis tests in F_2 distribution of six groundnut crosses

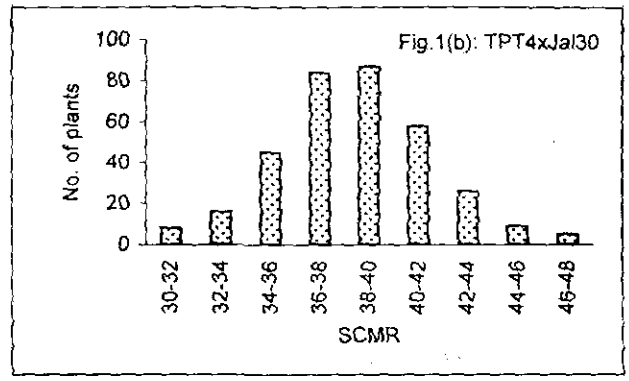
Cross	n	g_1 skew	b_2 kurt	g_2
TCGS 320 x Jal 30	368	-0.1175	2.88^{21}	-0.1179
Tirupati-4 x Jal 30	338	0.1263	3.13^{49}	0.1349
K-134 x Jal 30	379	-0.2680*	3.04^{24}	0.0424
VRI 2 x Jal 30	347	0.0261	2.590^{6**}	-0.4094
TCGS 29 x Jal 30	307	0.2796*	2.87^{94}	-0.1206
JL 24 x Jal 30	349	-0.0723	3.30^{58}	0.3058

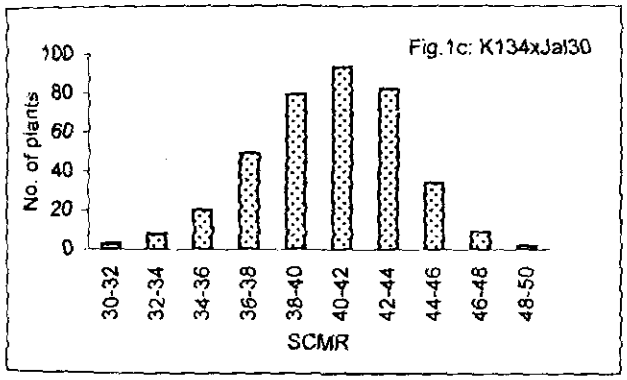
Table 4 Genetic parameters in F_2 populations of five groundnut crosses

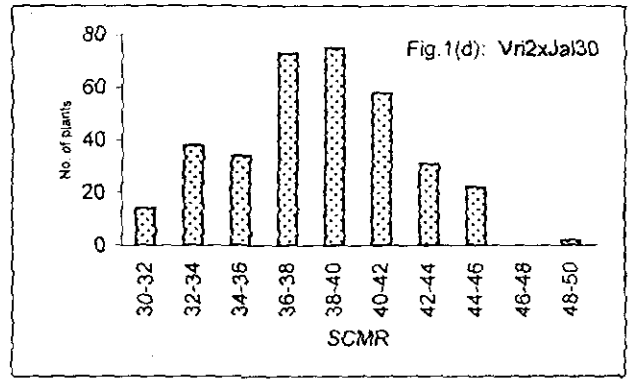
Cross	Genotypic variance	Phenotypic variance	GCV	PCV	Heritability % (in broad sense)	GA as % of the mean
TCGS 320 x Jal 30	9.82	11.7	8.03	8.77	84	5.42
Tirupati-4 x Jal 30	8.54	9.4	7.69	8.07	91	5.48
K-134 x Jal 30	9.04	9.9	7.48	7.83	86	5.33
Vri 2 x Jal 30	12.63	14.6	9.30	10.00	86	6.30
TCGS 29 x Jal 30	11.88	13.1	9.26	9.73	90	6.39
JL 24 x Jal 30	13.09	14.0	8.78	9.08	93	7.16

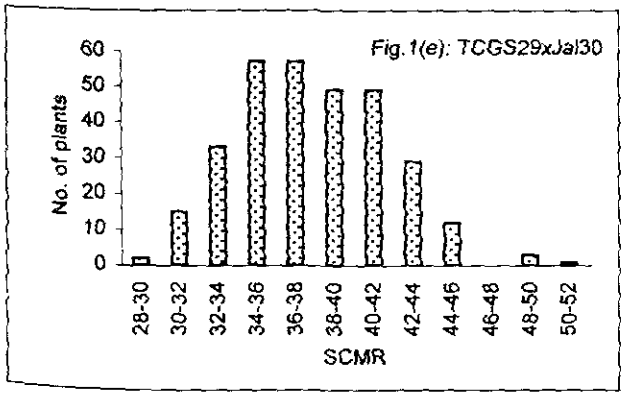
Fig. 1 (a) to (f): F_2 frequency distribution in different groundnut crosses for leaf chlorophyll content (in terms of SCMR)

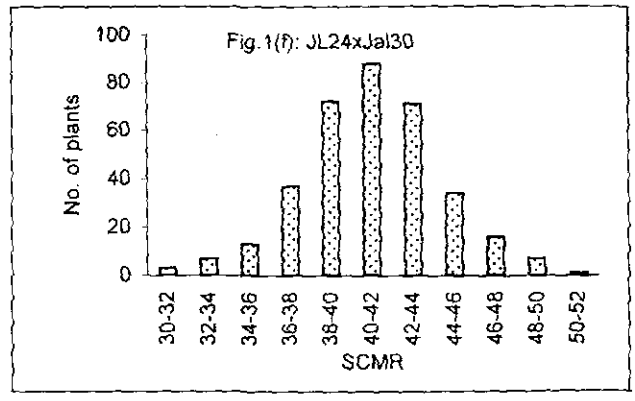












Transgressive individuals with SCMR that was higher than high SCMR parent, Jal 30 were observed in all the crosses but in higher number in cross combinations of K-134 x Jal 30 and JL 24 x Jal 30 (Table 2). Their occurrence supports the hypothesis that these parents differ in allele frequencies as discussed above. Transgressive individuals with low SCMR than the lower SCMR parent were also observed in all the cross combinations but in higher number in VRI-2 x Jal 30, TCGS 29 x Jal 30, Tirupati-4 x Jal 30 and TCGS 320 x Jal 30. As the transgressive individuals on either sides of the distribution could be captured within a population of 300-400, the trait may be probably governed by a fewer genes and oligogenic and may not be a polygenic trait. The oligogenes may be under the influence of several modifying factors, which might be responsible for the continuous variation observed in the trait. F_2 population derived from diverse crosses like VRI-2 x Jal 30 and TCGS 29 x Jal 30 would serve as a good mapping population for SCMR. F_2 population derived from low x high SCMR parents could be used to identify different DNA based molecular markers associated with high SCMR. These markers could be used for selection for high SCMR in segregating generations. Considerable work has been carried on molecular marker studies in groundnut (Gopalkrishna and Bhagwat, 2005).

Essomba *et al.* (1993) studied inheritance pattern of leaflet length and came to conclusion that it may be governed by oligogenes that show quasi-quantitative inheritance. In groundnut, many characters were reported to be oligogenic, which show quasi-quantitative inheritance. Quasi-quantitative inheritance could be recognized by the appearance of more than two stable phenotypes (Gruneberg, 1952) with mixed featured of both quantitative and qualitative traits resulting in confusing results as to the type of inheritance involved. The SPAD chlorophyll reading measures relative chlorophyll content that is responsible for intensity of green colour in leaves.

Phenotypically, we do observe different shades in leaf colour in groundnut i.e., from light green to bluish green. Thus, the studies of genetic parameters and distribution pattern in F_2 populations indicate that the trait, SCMR may probably be governed by a fewer genes acting in non-additive manner. Selection for high WUE through SCMR should thus be postponed to later generations where the confusing effects due to non-additive interaction i.e., dominance and epistasis get dissipated and the alleles get fixed. The process of fixation of favourable alleles could be made faster through biparental matings in early generations.

Acknowledgement: Financial support of Research and Communication Division, Ministry of Foreign Affairs, The Government of Netherlands, through APNL-BTU, Hyderabad is thankfully acknowledged.

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J. Oilseeds Res., 23(2) : 252-255 (2006)

Temporal variation in soil auxin production and biological properties as influenced by oxyfluorfen application to soybean, *Glycine max* (L.) Merril

A. Ramesh, S.D. Billore, O.P. Joshi and Sushil K. Sharma

National Research Centre for Soybean, Khandwa Road, Indore-452 017, MP

(Received: February, 2005; Revised: September, 2005; Accepted: December, 2005)

Abstract

Field experiments were conducted during rainy season of 1999 and 2000 at Research Farm, National Research Centre for Soybean, Indore on Sarol soil series to assess the effect of oxyfluorfen on periodical changes in auxin production and its relationship with pertinent biochemical properties. The treatments included graded doses of oxyfluorfen from 250 ml to 1000 ml a. I. /ha applied either as pre-plant incorporation or pre-emergence application and a weedy check. Auxin production and biochemical properties were monitored at 30, 45, 60 days after sowing (DAS) and at harvest. During both the years, pre-plant incorporation of oxyfluorfen either stimulated or did not cause appreciable variation in auxin production after initial suppression in its activity (30 DAS), while application of oxyfluorfen as pre-emergence herbicide either stimulated or did not significantly affect auxin production irrespective of dose and periods of sampling over control. Similar trend was also observed in other pertinent biochemical properties *viz.*, dehydrogenase activity, microbial biomass C and N. Mean auxin production was also positively associated with dehydrogenase activity, microbial C, microbial N, grain yield and N content. The study revealed that application of oxyfluorfen did not significantly affect auxin production and other biological properties and can be recommended for weed control in soybean without affecting soil health.

Key words: Dehydrogenase activity, indole acetic acid (IAA), microbial biomass, oxyfluorfen, soybean

Introduction

Microbial production of plant hormones like auxins could have an important ecological role in altering plant growth and development. Many soils contain compounds that exhibit strong auxin like activity and depend in their IAA synthesizing capacity depending on the soil and crop management practices. In recent years, application of herbicides is becoming a wide spread practice as weeds often pose a serious threat to sustainable soybean production. It has been reported that on account of weed competition, the yield reduction in soybean may be up to 69% (Billore *et al.*, 1999). Intensive use of herbicides may have an impact on auxin production and other important biochemical properties and can be used as a tool to document the ecological effect of herbicides application to soil. Therefore, the present study was initiated to assess the effect of oxyfluorfen on (a) periodical changes in auxin production and pertinent biological properties *viz.*, dehydrogenase activity, and microbial biomass (b) relationship between auxin production and biological parameters

Material and methods

Field experiments were conducted during *kharif* of 1999 and 2000 at Research farm, National Research center for Soybean, Indore to assess the effect of oxyfluorfen on auxin production and its relationship with pertinent biological properties. The soil of the experimental site belongs to Sarol series (Iso-hyperthermic, montmorollinitic, typic chromusterts) with: clay 53.2 %, pH 8.1, organic carbon 5.2 g/kg, Olsen's P 4.2 ppm and ammonium acetate K 242 ppm. There were a total of 9 treatments comprising of graded doses of oxyfluorfen from 250 ml a.i./ha to 1000 ml a.i./ha applied either as pre-plant incorporation (PPI) or pre-emergence application (PE) and an untreated control replicated thrice in an Randomized Block Design. The plot size maintained was 6m x 3.6m and the crop was raised under rainfed conditions. Soybean 'JS 335' was sown on 26th June 1999 and 2000 with 20:26:17 kg NPK/ha through urea, single super phosphate and muriate of potash, respectively. Soil samples were collected at periodical intervals *viz.*, 30, 45, 60 days after sowing (DAS), and at harvest to study changes in auxin production, dehydrogenase activity, microbial biomass C and N. L- Tryptophan derived auxin production was assayed by the method of Sarwar *et al.* (1992) and expressed as mg IAA-equivalents/kg soil. Dehydrogenase activity (DHA), a measure of microbial activity was assayed by the method of Cassida (1977) and expressed as μ mol TPF/g soil/24 hr. Microbial biomass carbon (MB-C) and N (MB-N) was determined by the fumigation-extraction method with 0.5 M K_2SO_4 (Vance *et al*,. 1987).

Results and discussion

Rainfall distribution and weed biomass: During *kharif* 1999, a total of 780 mm rainfall was received during the crop growth period. However, during 2000, a total of only 325 mm was received creating severe moisture stress. The distribution of rainfall was also erratic. The crop experienced dry spell during July 17 to August 10 and literally no rain after August 20 coinciding with full bloom stage (R2). During September and October months dry spell continued and the resultant stress not only hampered seed filling but also brought about forced maturity.

Application of oxyfluorfen significantly decreased weed dry biomass (g/m^2), irrespective of method and level of application of herbicide as compared to control during both the years of study (Table 1). It is also to be noted that application of oxyfluorfen as pre emergence was found to be effective *vis-à-vis* pre-plant incorporation as evidenced by decreased weed dry biomass. The weed dry biomass was higher during 2000 as compared to 1999 season.

Auxin production: Application of oxyfluorfen as pre-emergence herbicide either stimulated or did not significantly affect auxin production irrespective of the periods of sampling during both the years of study. However, application of oxyfluorfen as pre-plant incorporation showed transient inhibition at 30 DAS during both the years and a non-significant or stimulatory effect at later stages of crop growth over control (Table 2). This suggests that herbicides degrade over time and degraded products/activating co-metabolites might have acted as a source for microbial proliferation at later stages of crop growth (Perucci *et al.*, 1999). Moreover, Wardle and Parkinson (1990) concluded that changes in microbial variables only occurred at herbicide concentration much higher than that recommended for field application. Periodical changes indicated an increase in auxin production up to 60 DAS and a decline at harvest irrespective of whether oxyfluorfen was applied or not. IAA being one of the most physiologically active auxins and is a common product of L-Tryptophan metabolism by soil micro-flora, its production depends on substrate availability (Arshad and Frankenberger, 1991). Microbial growth during crop growth is often stimulated by the continual input of readily assimilated organic substrates from the roots might have contributed for increased microbial synthesis of IAA. Application of oxyfluorfen as pre emergence significantly increased auxin production up to 750 ml a.i./ha and decreased at the highest dose of application. Pre-plant incorporation did not significantly influence auxin production irrespective of the dose at which it is applied.

Dehydrogenase activity and soil microbial biomass: During both the years, application of Oxyfluorfen significantly increased dehydrogenase activity, microbial biomass C and N over control (Table 3). It was found that application of oxyfluorfen as pre-emergence herbicide stimulated microbial variables as compared to pre-plant incorporation. Similar increase in dehydrogenase activity as influenced by herbicide application was also reported by Ramesh *et al.* (2000) and also for microbial biomass (Vischetti *et al.*, 2002). The study also indicated that temporal variation in dehydrogenase activity, microbial biomass C and N also followed a similar trend as that of auxin production. However, the interaction between oxyfluorfen application and periods of sampling was found to be non-significant. Attempts were also made to relate auxin production to pertinent biological properties. Mean auxin production was better explained by a strong positive association with MB-C ® = 0.932**) and MB-N ® = 0.787**) indicating that auxin is synthesized by proliferating soil microorganisms in response to the presence of suitable substrate. This is further corroborated by a strong relationship with dehydrogenase activity ® = 0.664**) as dehydrogenase activity appeared to be more dependent on the microbial state of the soil or on the biological activity of the microbial population than on any free enzyme present.

Table 1 Effect of oxyfluorfen on weed dry biomass (g/m^2) in soybean

Treatment	1999						2000					
	Days after sowing											
	30 DAS			60 DAS			30 DAS			60 DAS		
Oxyfluorfen	Monocot	Dicot	Total	Monocot	Dicot	Total	Monocot	Dicot	Total	Monocot	Dicot	Total
250 ml a.i /ha PE*	7.0	3.0	10.0	14.0	5.0	19.0	20.0	36.00	56.00	104.00	269.32	373.32
250 ml a.i /ha PPI**	5.0	2.0	7.0	16.0	5.0	21.0	20.0	53.68	73.68	145.32	332.00	477.32
500 ml a.i /ha PE	6.0	0.0	6.0	7.0	0.0	7.0	25.32	23.68	49.00	206.68	140.00	346.68
500 ml a.i /ha PPI	40.0	2.0	42.0	12.0	1.0	13.0	33.32	51.32	84.64	312.00	266.32	578.32
750 ml a.i /ha PE	2.0	2.0	4.0	3.0	0.0	3.0	5.32	20.00	25.32	52.00	106.68	158.68
750 ml a.i /ha PPI	3.0	0.0	3.0	16.0	5.0	21.0	30.68	38.68	69.36	119.72	234.68	354.40
1000 ml a.i /ha PE	2.0	1.0	3.0	15.0	6.0	21.0	22.68	10.68	33.36	59.32	157.32	216.64
1000 ml a.i /ha PPI	20.0	1.0	21.0	21.0	6.0	27.0	28.0	28.00	56.00	240.00	161.32	401.32
Control	75.0	11.0	86.0	28.0	11.0	39.0	58.68	70.16	128.84	152.00	422.68	574.68
LSD (P=0.05)	1.65	1.40	2.78	1.80	1.30	2.50	50.0	33.12	55.24	176.24	186.20	237.08

PE* = Pre-emergence application; PPI** = Pre-plant incorporation

Table 2 Effect of oxyfluorfen on periodical changes in soil auxin production (mg IAA equivalents/kg soil) in soybean

Treatment (T)	1999					2000				
	Days after sowing (P)									
Oxyfluorfen	**30**	**45**	**60**	**Harvest**	**Mean**	**30**	**45**	**60**	**Harvest**	**Mean**
250 ml a.i /ha PE*	146	162	176	107	148	107	120	133	80	110
250 ml a.i /ha PPI**	132	158	171	96	139	100	117	124	80	105
500 ml a.i /ha PE	152	174	193	119	160	112	134	133	85	116
500 ml a.i /ha PPI	137	160	178	107	146	97	120	127	82	107
750 ml a.i /ha PE	156	182	213	121	168	109	137	139	89	119
750 ml a.i /ha PPI	137	164	175	110	147	102	120	128	77	107
1000 ml a.i /ha PE	140	177	188	113	155	112	129	133	89	116
1000 ml a.i /ha PPI	130	162	168	104	141	104	126	128	82	110
Control	140	154	162	100	139	107	115	122	80	106
Initial					88					62
Mean	**141**	**166**	**180**	**109**		**106**	**124**	**130**	**83**	
LSD (P=0.05)										
T					7					4
P					5					3
M					3					2
TXP					10					6
TxPxM					NS					NS

M = Mode of application; PE* = Pre-emergence application; PPI** = Pre-plant incorporation

Table 3 Effect of oxyfluorfen on periodical changes in dehydrogenase activity and microbial biomass C and N

Treatment (T)	Dehydrogenase activity (μ mol TPF/g/soil/24 h)		Microbial biomass C (mg C/kg soil)		Microbial biomass N (mg N/kg soil)	
Oxyfluorfen	***1999***	***2000***	***1999***	***2000***	***1999***	***2000***
250 ml a.i/ha PE*	0.294	0.256	252	205	29	22
250 ml a.i/ha PPI**	0.276	0.234	243	200	27	20
500 ml a.i/ha PE	0.299	0.262	258	214	29	24
500 ml a.i/ha PPI	0.281	0.256	241	203	23	23
750 ml a.i/ha PE	0.321	0.278	249	220	33	27
750 ml a.i/ha PPI	0.272	0.252	233	207	29	21
1000 ml a.i/ha PE	0.283	0.268	245	214	31	27
1000 ml a.i/ha PPI	0.254	0.266	233	194	26	20
Control	0.240	0.226	235	198	23	20
Periods (P) of sampling (Days after sowing)						
30	0.247	0.235	238	203	27	21
45	0.316	0.277	255	214	28	25
60	0.330	0.293	261	223	32	25
Harvest	0.221	0.207	221	185	23	18
Initial	0.192	0.178	204	188	18	18
LSD (P=0.05)						
T	0.028	0.033	9	7	4	4
P	0.019	0.022	7	5	3	3
M	0.012	NS	4	3	3	2
TxP	NS	NS	NS	NS	NS	NS
TXPxM	NS	NS	NS	NS	NS	NS

M = Mode of application; PE* = Pre-emergence application; PPI** = Pre-plant incorporation

During both the years of study, application of oxyfluorfen as pre-emergence herbicide significantly increased seed yield of soybean, while pre-plant incorporation (>750ml a. i./ha) did not significantly affect seed yield over control. The plausible explanation of lower seed yield during 2000 as compared to 1999 might be a consequence of moisture stress at critical stages of crop growth (full bloom-R2, Seed fill and maturity-R5-R7). More over, increased weed dry biomass during *kharif* 2000 *vis-a-vis* to 1999 might also contributed to decreased seed yield. Generally, seed N content also increased due to oxyfluorfen application over control (Table 4). Mean auxin production was also significantly associated with grain yield (r=0.948**) and N content (r=0.758**) indicating that increased production of microbially mediated auxin production influenced soybean productivity.

In conclusion, the study revealed that application of oxyfluorfen did not significantly affect auxin production and other biochemical properties and increased soybean yield and can be recommended for weed control in soybean without affecting soil health.

Table 4 **Effect of oxyfluorfen on seed yield and N content in soybean**

Oxyfluorfen	Seed yield (kg/ha)		Seed N content (%)	
	1999	2000	1999	2000
250 ml a.i./ha PE*	1138	460	6.38	6.13
250 ml a.i./ha PPI**	1019	389	6.27	5.98
500 ml a.i./ha PE	1188	392	6.23	6.07
500 ml a.i./ha PPI	1034	257	6.29	5.89
750 ml a.i./ha PE	1087	548	6.45	6.15
750 ml a.i./ha PPI	972	316	6.35	6.03
1000 ml a.i./ha PE	1138	521	6.48	6.23
1000 ml a.i./ha PPI	952	383	6.14	5.89
Control	807	250	5.96	5.80
LSD (P=0.05)	190	109	0.20	0.18

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J. Oilseeds Res., 23(2) : 256-259 (2006)

Studies on the mechanism of host plant resistance to *Spodoptera litura* (F.) in elite breeding lines of groundnut, *Arachis hypogaea* L.

R.K. Patil, K.G. Parameshwarappa and P.V. Kenchanagoudar

Oilseeds Scheme, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad-580 005, Karnataka

(Received: February, 2005; Revised: July, 2005; Accepted: September, 2005)

Abstract

The investigations have been carried out for four years from 1996 to 1999 involving elite genotypes of groundnut to assess the yielding potentiality over different agroclimatological conditions and also to understand the mechanism of resistance to a major defoliator *Spodoptera litura* (F_1). Among the genotypes evaluated in the coordinated trials, Dh 53 was found to be superior in its performance for both pod and kernel yield over other test entries and checks. Genotype DH 53 surpassed all other entries for pod yield under unprotected conditions and hence considered to be a resistant variety groundnut *S. litura*. Measure of relative water content, laminar thickness, epidermal thickness, number and size of stomata as well as larval mortality, gain in body weight and fecundity indicated the role of antibiosis conferring resistance to *S. litura* in Dh 53 genotype.

Key words: *Spodoptera litura*, antibiosis

Introduction

Groundnut (*Arachis hypogaea* L.) is a major oilseed crop grown predominantly during rainy season in the country. It is also grown in post-rainy or summer season with irrigation. The average productivity in rainy season is low (<1000 kg/ha) when compared to summer grown crop (1500 kg/ha) (Anon., 2002). This is mainly because the crop is well subjected to vagaries of rainfall and also damage due to pest and diseases. Among several pests attacking groundnut, *Spodoptera litura* (F.) is the major defoliator causing considerable yield loss ranging from 22 to 71% (Kulkarni, 1989; Patil *et al.*, 1994). As groundnut is hardly given any plant protection measures to control the pests and diseases on account of high seed cost, integrated pest management is the only viable proposition in which inclusion of resistant variety is indispensable.

Therefore, efforts have been made in the present study to identify promising genotypes for pod yield and mechanism of resistance to *S. litura*.

Material and methods

Two sets of experiments were constituted to assess the yielding ability of the genotypes across locations and to understand the mechanism of resistance to *S. litura*. The materials in the first set included were four advanced breeding lines *viz.*, Dh 53, ICRG 91112, ICRG 91116, VG 9513 and two checks JL 24 and SB-XI. These genotypes were chosen based on rigorous yield test in the All India Coordinated trials for three years from 1997 to 1999 over two locations *viz.*, Kanke and Jhargram and also preliminary screening for *S. litura* damage. The yield trials were conducted in the Randomized Block Design with three replications in IVT SI and SII stage (four in AVT). The compiled data pertaining to pod yield and kernel yield has been utilized to assess the yielding ability of different genotypes.

A separate trial for studying mechanism of resistance was laid out for two seasons during *kharif*, 1996 and 1997 at the Oilseeds Scheme of UAS, Dharwad. The genotypes included were Dh 52, Dh 53, Dh 55, Dh 56, Dh 57, Dh 73, Dh 74, ICGV 86350 all exhibiting resistance to *S. litura* and two checks ICGV 86590 (resistant) and JL 24 (susceptible). Each genotype in the trial has been assigned with protected and unprotected plots and the treatments were evaluated in a Split Plot Design with three replications during both the years. Young larvae of *S. litura* reared in laboratory were released into the unprotected plots to create the maximum pest incidence and foliar damage. At the same time care was taken to control pest and disease complex in the protected plots by suitable spray measures. The observations were recorded on pod yield and per cent leaf damage in both protected and unprotected plots. A parallel experiment was run in the laboratory to establish host plant resistance mechanism by artificially feeding of *S. litura* larvae with foliage of genotypes under evaluation in the field. For this, neonate larvae from one egg mass (200 larvae/egg mass) constituted the treatment in a replication and studied in Randomized Block Design with three replications. They were provided with fresh and undamaged leaves at an

interval of 24 hrs. The newly hatched larvae were transferred to aluminium trays (maintained at 26±1°C and 80-85% RH). As the larvae grew up they were transferred to bigger containers layered with 3 to 4 cm thick sterilized saw dust to facilitate pupation. Then pupae were sexed, paired and kept in rearing cage for emergence and oviposition. The observations were recorded on host plant for number of stomata, length and breadth of stomata and relative water content. Observations on growth parameters of larvae included the per cent mortality, gain in body weight at 5, 10 and 15 days of rearing and number of eggs per female (fecundity). The growth index of larvae grown on each genotype was also worked out.

Results and discussion

The summary performance of genotypes for pod and kernel yield (Table 1) revealed that the entry Dh 53 gave the highest pod yield of 2926 kg/ha with an increase of 47.9% and 42.2% over JL 24 (national check) and SB-XI (zonal check). The entries ICRG 91116 and VG 9513 were next only to Dh 53 in performance either for pod or kernel yield. This variety has an added advantage of resistance to *S. litura* pest and also foliar diseases like late leaf spot and rust.

The resistance nature of a variety can be ascertained through its high yield potential at threshold level of pest populations (under unprotected conditions) and the least decline in pod yield between protected and unprotected conditions. In the evaluation of different genotypes (Table 2), it has been observed that Dh 53 has recorded the highest pod yield (2975 kg/ha) under unprotected conditions as well as the least decline in pod yield (22.20%) and foliage damage (46.80%). Therefore, it can be considered as a resistant variety to *S. litura*. However, the lowest pod yield (2415 kg/ha) as well as higher reduction in pod yield (43.06%) was noticed in the check variety JL 24 and can be considered to be a susceptible variety. As far per cent reduction in foliage was considered, though ICGV 86350 followed by Dh 74 experienced the highest damage there was no corresponding decline in pod yield under unprotected conditions as well as in their per cent decline and therefore, can be treated as next best resistant entry Dh 53. In cultivated groundnut, the varieties developed so far lack resistance to *S. litura*.

Analysis of different genotypes for the mechanism of resistance they possessed to *S. litura* (Table 3) indicated that the genotype Dh 53 had the lower relative water content (RWC) as compared to JL 24 and ICGV 86590. Further, this genotype had higher laminar and epidermal thickness compared to check JL 24. Feeding of young larvae on the leaves of this genotype had shown higher larval mortality is attributed to antibiosis mechanism (Table 4). Those larvae fed on Dh 53 foliage exhibited lower fecundity in the adult females emerged from pupae support the role of antibiosis. The above findings are in agreement with earlier reports by Stevenson *et al.* (1993) and Patil *et al.* (1995) in groundnut. Thus, Dh 53 would no doubt offer durable resistance to *S. litura*. Cultivation of such genotypes in larger area may reduce further pest build up and elevate the crop yields. Considering the parentage of Dh 53 it originated from ICGV 86276, which possessed resistance to *S. litura* and had some undesirable pod features. Therefore, this parent was involved in hybridization with JL 24 to improve pod features. The derivative of this cross Dh 53 has improved shelling and pod features compared to its paternal parent ICGV 86276.

Table 1 Performance of different groundnut genotypes in coordinated trials (spanish bunch) over years in Zone IV

Genotype		IVT-I (Kharif, 1997)		Mean	IVT-II (Kharif, 1998)		Mean	AVT-I (Kharif, 1999)		Mean	Grand mean	% increase over	
		Kanke	Jargram		Kanke	Jargram		Kanke	Jargram			JL-24	SB XI
Dh-53	P	1240	3976	2608	3511	3749	3630	1493	3972	2733	2926	47.9	42.2
	K	868	1974	1421	3019	2522	2771	970	2512	1741	1918	56.6	48.4
ICRG-91116	P	586	4722	2654	1844	5133	3489	1105	3030	2068	2569	35.4	30.2
	K	416	2866	1641	1420	3532	3476	807	1820	1314	1686	43.3	35.8
VG-9513	P	1096	4213	2655	2469	3750	3110	1748	2297	2023	2452	27.1	23.5
	K	833	2528	1681	1901	2577	2239	1311	1361	1336	1648	38.7	31.4
JL-24	P	756	3021	1889	1898	3449	2674	1008	1997	1503	1892	-	-
	K	576	1665	1120	1423	2035	1729	736	1142	939	1182	-	-
SB XI	P	810	3004	1907	2199	3507	2853	874	2219	1547	1963	-	-
	K	608	1608	1108	1715	2138	1927	655	1272	967	1240	-	-
ICRG-91112	P	664	5834	3249	1365	5303	3334	480	3097	1789	2561	-	-
	K	478	3558	2018	1004	3307	2156	327	1912	1120	1638	-	-
CD (P=0.05)	P	115	767	-	337	702	541	303	458	273			
	K	84	477	-	255	439	353	212	272	242			
CV (%)	P	8.9	14.1	-	14.7	13.0	14.2	20.7	12.3	15			
	K	8.9	15.8	-	14.6	13.5	14.3	20.6	12.2	15			

P = Pod yield (kg/ha); K = Kernel yield (kg/ha)

Table 2 Performance of groundnut genotypes for pod yield (%) and defoliation under protected and unprotected conditions

Genotype	*Kharif*, 1996				*Kharif*, 1997				Pooled				% decline over mean	
	Unprotected		Protected		Unprotected		Protected		Unprotected		Protected			
	pod yield (kg/ha)	% leaf damage	Pod yield (kg/ha)	% leaf damage	Pod yield (kg/ha)	% leaf damage	Pod yield (kg/ha)	% leaf damage	Pod yield (kg/ha)	% leaf damage	Pod yield (kg/ha)	% leaf damage	Pod yield	Leaf damage
Dh-53	3277	13.8	3844	6.2	2672	14.0	3432	6.8	2975	13.89	3638	6.5	22.2	46.8
Dh-52	3189	14.7	3862	6.6	2259	15.9	3219	7.1	2724	14.91	3540	6.9	29.9	46.1
Dh-55	2992	14.7	3871	7.0	2448	15.1	3496	7.3	2720	14.89	3683	7.0	35.4	47.0
Dh-56	2859	15.1	3870	6.9	2491	15.2	3356	7.4	2675	15.18	3614	7.1	35.1	47.0
Dh-57	3229	14.4	3789	6.6	2397	13.9	3255	6.4	2813	14.18	3522	6.5	25.2	49.2
Dh-73	2914	16.5	3608	10.4	2914	17.7	3755	10.6	2814	17.11	3682	10.5	30.8	61.4
Dh-74	2948	17.7	3825	9.7	2923	17.8	3353	9.8	2938	17.76	3589	9.7	22.2	54.7
ICGV 86350	2797	20.5	3855	11.8	3605	19.5	2685	12.7	2741	19.75	3730	12.3	36.1	62.1
ICGV 86590	2976	18.9	3617	11.5	2313	18.6	3137	12.1	2644	18.75	3377	11.6	27.7	61.9
JL-24	2582	36.6	3693	19.0	2249	38.0	3218	19.8	2415	37.03	3455	19.4	43.1	52.4
Mean	2977	18.2	3783	9.5	2535	18.5	3383	10.0	2756	18.25	3583	9.7	30.0	53.4
For comparing means of	SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)			
Genotypes (G)	39.0	0.87	110.0	2.44	48.92	2.35	128.0	0.84	42.52	1.57	119	0.56		
Spray (S)	29.14	0.55	82.0	1.54	30.94	1.49	87.08	0.53	26.89	0.99	75	0.36		
G x S interaction	82.00	1.74	259.0	NS	97.85	NS	NS	1.68	85.05	3.13	NS	1.13		

Table 3 Anatomical characters of different genotypes imparting resistance to *S. litura* in groundnut

Genotype	Laminar thickness (μ)	Epidermal thickness (μ)	Stomata/ Microscopic field (10x45X)	Stomatal length (μ)	Stomatal breadth (μ)	Relative water content (%)
Dh-53	296.00c	32.00abc	9.1bc	76.7bc	118.7abc	60.45bcd
Dh-52	255.00e	26.00e	9.7bc	81.00bc	121.3ab	60.6bcd
Dh-55	268.00de	27.00be	10.3bc	82.7b	119.3abc	60.8bc
Dh-56	317.00bc	31.00bcd	10.00bc	79.7bc	109.7bc	60.7bcd
Dh-57	304.33c	36.00a	10.3bc	73.7c	111.7bc	58.3d
Dh-73	289.00cd	30.00cde	9.33cd	82.3b	117.7abc	62.5b
Dh-74	351.00a	32.00abc	8.00b	80.00bc	110.7bc	62.9ab
ICGV 86350	295.00cd	35.00ab	11.3b	76.00bc	111.3bc	59.6cd
ICGV 86590	338.00ab	32.00abc	10.3bc	76.00bc	106.7c	61.7bc
JL-24	213.00f	21.00f	15.00a	93.00a	126.7a	65.02a
'r' value	0.427*	415*	-0.389*	-0.406*	0.114NS	-0.575**

r=Correlation value; * Significant at *P=0.05*; ** Significant at *P=0.01*;
Means followed by the same alphabet in a vertical column did not differ significantly (P=0.05) by DMRT

Table 4 Biology of *S. litura* on different groundnut genotypes

Genotypes	% larval mortality			% larval survival	Five larval weight (g)			Larval duration (days)	Growth index	Fecundity/ female
	5 DAH	10 DAH	15 DAH		5 DAH	10 DAH	15 DAH			
Dh-53	48.00a	56.13a	59.20a	37.60c	3.66d	45.33d	236.7g	25.67ab	1.38b	1053f
Dh-52	44.53a	52.27ab	59.73a	38.40c	4.33cd	47.33g	237.7g	25.33ab	1.45b	1100cf
Dh-55	39.07ab	54.67a	57.73a	39.20c	4.67cd	54.67e	247.3ef	25.33ab	1.49b	1124e
Dh-56	40.00ab	53.20a	56.80a	40.40c	4.67cd	57.67fg	245.7f	25.00ab	1.54b	1056f
Dh-57	45.33a	50.93ab	55.87a	40.80bc	5.33c	49.33f	251.3e	25.33ab	1.55b	1164e
Dh-73	42.53ab	48.80ab	55.07a	40.20bc	7.33c	67.67d	275.7d	23.67bc	1.63b	1320b
Dh-74	44.40b	50.53ab	56.27a	39.60c	7.67b	65.97cd	280.0d	24.00abc	1.58b	1365cd
ICGV-86590	32.53b	36.40c	42.80b	51.47ab	8.67b	71.00c	250.7b	23.00c	2.13ab	1426b
JL-24	20.53c	30.67c	44.00b	60.80a	10.33a	94.00a	465.0a	21.33d	2.77d	1718a

It is also important to that the parameters measured for possessing mechanism of resistance to *S. litura* in Dh 53 are also coinciding with the parameters of drought tolerance. This is evident from relatively lower number of stomata, stomatal size and low RWC, which are essential for minimizing the transpiration rate. During characterization of germplasm it was noticed that Dh 53 possessed high density of trichomes beneath the leaf surface. Thus, Dh 53 can be considered to have multiple resistance for both biotic as well as abiotic stresses. However, screening of genotypes in the drought resistance nursery is essential to confirm its performance.

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J. Oilseeds Res., **23**(2) : 260-262 (2006)

Bionomics and predatory potential of *Cheilomenes sexmaculata*, Coleoptera : Coccinellidae on *Lipaphis erysimi* (Homoptera : Aphididae)

Narendra Kumar, V.S. Malik and J.S. Rana

Department of Entomology, CCS Haryana Agricultural University, Hisar-125 004, Haryana

(Received: May, 2005; Revised: November, 2005; Accepted: December, 2005)

Abstract

The biology of *Cheilomenes sexmaculata* (Fabricius) on *Lipaphis erysimi* (Kaltenbach) was studied under laboratory conditions. The female laid cigar shaped, pale yellow eggs in clusters. Fully developed larva was black in colour with white patches on its body bearing white spines. The adult was orange red with elytra having two black zig-zag lines on each elytron. The average duration of first, second, third and fourth instar larva was 1.87, 2.56, 2.35 and 4.17 days, respectively. The average larval duration was 10.94 days followed by pupal period of 5.07 days. On an average, the male adult survived for 24.06 days, whereas the female survived for 27.58 days. Pre-oviposition, oviposition and post-oviposition period was 4.11, 22.15 and 3.96 days, respectively. The fecundity was 183.42 eggs. Incubation period was 2.91 days with hatchability 74.90%. Larva consumed an average of 14.1, 29.2, 33.5 and 79.8 aphids during I, II, III and IV instars, respectively, with a total of 156.6 nymphs of *Lipaphis erysimi* during whole larval duration. The prey consumption by an adult female and male was 496.4 and 336.0 aphids, respectively.

Key words: Rapeseed-mustard, *Cheilomenus sexmaculata*, biology, predatory potential, *Lipaphis erysimi*

Introduction

The predaceous coccinellids are known to play an important role in aphid population regulation (Agarwala and Choudhuri, 1995) due to their high predatory efficiency (Hodek, 1973) with a considerable degree of success. These coccinellids are highly mobile over plant parts, are efficient predators of other sucking insects like, whiteflies, leafhoppers, plant hoppers, scale insects and mealy bugs (Rai *et al.*, 2003). *Cheilomenes sexmaculata* (Fabricius) is one of the most important aphidophagous predator among all the predatory coccinellids. It is commonly known as zig-zag ladybird beetle. Biology and predatory efficiency of a coccinellid beetle play an important role in understanding its predatory behaviour. Inspite of a few earlier reports (Bagal and Trehan, 1943; Rajamohan and Jayaraj, 1974; Saha, 1987; Gautam, 1989; Babu, 2001) on its general efficiency and record in different crop ecosystem, there is no specific information about its biology and predatory efficiency in rapeseed and mustard crops in northern India. Hence, the present studies were planned to know its bionomics and predatory potential with *Lipaphis erysimi* (Kalt.) as prey.

Material and methods

The experiments on bionomics and predatory potential of *Cheilomenes sexmaculata* were carried out during 2003-04 in the Department of Entomology, CCS Haryana Agril. University, Hisar at prevailing room temperature and humidity from 15th Feb. to 25th April, 2004.

Adult beetles (male and female) of *C. sexmaculata* were collected from the mustard fields and kept in laboratory in glass jar (15cm x 10cm) for obtaining eggs. These beetles were provided with abundant number of aphids daily. The glass jars were covered with muslin cloth. Eggs laid by gravid female on the surface of glass jar were removed/isolated daily with the help of a moist camel hair brush, while those deposited on the leaf surface were removed along with the leaf and were transferred to Petri dishes (15 cm diameter). The eggs thus obtained were used for further observations on durations of different life stages. A total of 10 replications with 100 eggs each were maintained in Petri dishes (15 cm diameter) for observing incubation period and number of eggs hatched were recorded twice daily at 0900 and 1800 hr.

For recording the duration and predatory efficiency of gurbs and adults of *C. sexmaculata*, counted numbers of *L. erysimi* nymphs were provided. For this, ten newly hatched first instar grubs were individually placed in plastic tubes (7.5 cm x 2.5 cm). Such grubs were given 10 first and second instar aphids. As these grubs developed into second, third and fourth instar, they were fed with daily 20 first and second instar, 30 third and fourth instar and 40 third and fourth instar aphid nymphs, respectively. For studying adult feeding potential, newly emerged adults were provided with 3rd and 4th instar aphid nymphs as food. Fresh aphid food was replaced daily and 10 replications were maintained. The unconsumed aphids were counted after every 24 hr to work out the actual

number of aphids consumed by the predator. Duration of pupal, pre-oviposition, post-oviposition period, and fecundity of beetle developed on *Lipaphis erysimi* were also recorded. For recording fecundity, 100 pairs of beetle were reared in glass jar and total numbers of eggs laid by female during its life span were recorded.

Results and discussion

Morphology of immature stages: Female deposited eggs in clusters. Freshly laid eggs of *C. sexmaculata* were shining, cigar shaped and pale yellow in colour. The newly hatched larva was grey in colour and sluggish, which changed to black gradually. Fully developed larva was light black in colour with white patches on its body bearing white spines. The adult was more or less spherical with orange red elytra, with two black zig-zag lines on each elytra.

Duration of different life stages:

Larval duration: The observations revealed that predator passed through four larval instars to become a pupa. The average duration of first, second, third and fourth instars larva was 1.87, 2.56, 2.35 and 4.17 days, respectively. The average larval duration was 10.94 0.70 days with a range of 9-14 days. A pupal period of 5.07 days, with a range from 4-7 days was noticed during investigation (Table 1).

These findings are in conformity with earlier reports by Saharia (1983); Eswaramoorthy *et al.* (1998) and Bhadauria *et al.* (2001). However, Sharma (1974) reported longest larval period i.e. 21 days on *L. erysimi*. On the contrary, Rajamohan and Jayaraj (1974) reported shorter larval period (5.55 days) with *A. craccivora* as prey. Little variation in duration might be due to the environmental conditions prevailing in different regions during the period of study.

Adult duration: On an average, the male adult survived for 24.06 days, whereas, the female survived longer than male (27.58 days) showing close conformity with the findings of Saharia (1983); Varma *et al.* (1993) and Eswaramoorthy *et al.* (1998). Pre-oviposition, oviposition and post-oviposition period of a female was 4.11, 19.50 and 3.96 days, respectively and a female laid 183.42 eggs during its life and these are in line with the findings of Saharia (1983); Bhadauria et al. (2001) and Rai *et al.* (2003). Incubation period of eggs was recorded to be 2.91 days, which is in conformity with the results of Varma *et al.* (1993) and Bhadauria *et al.* (2001). Saharia (1983) reported incubation period of 6.30 days with *Myzus persicae* (Sulz.), which is longest as compared to other studies with an average hatchability of 74.90 % showing similarity with Veeravel and Baskaran (1995) on *Aphis gossypii* Glover.

Predatory potential: The observations recorded on the predatory potential (Table 2) revealed that the feeding rate of different larval instars varied greatly. First instar larva consumed an average of 14.1 aphids ranging from 8-22 aphids. Second instar larva consumed an average of 29.2 aphids ranging from 18-45 aphids. Third instar larva consumed an average of 33.5 aphids ranging from 25-48 aphids and the last fourth instar larva consumed an average of 79.8 aphids ranging from 52-106 aphids.

Table 1 Biological parameters of *Cheilomenes sexmaculata* (Fabricius) with *Lipaphis erysimi* (Kalt.) as prey

State of the predator	Mean ± SD*		
Larval duration (days)		Larval stage	Temperature : 16-23.1°C
1st instar	1.87±0.18		RH : 61-69%
2nd instar	2.56±0.24		
3rd instar	2.35±0.23		
4th instar	4.17±0.40		
Total larval duration	10.94±0.70		
Pupal period (days)	5.07±0.28	Adult and pupal stages	Temperature : 20.9-32.15°C
Adult longevity (days)			RH : 27-68%
Male	24.06±3.32		
Female	27.58±3.81		
Incubation period (days)**	2.91±0.20		
Hatchability (%)**	74.90±9.79		
Pre-oviposition period (days)	4.11±0.39		
Oviposition period (days)	19.50±2.34		
Post-oviposition period (days)	3.96±0.34		
Fecundity (eggs per female)	183.42±20.08		

* Based on 100 individuals of *Cheilomenes sexmaculata* (Fab.); ** Based on 1000 eggs of *Cheilomenes sexmaculata* (Fab.)

Table 2 **Predatory potential of *Cheilomenes sexmaculata* (Fabricius) reared on *Lipaphis erysimi* (Kalt.)**

State of the predator	Mean number of aphid consumed during individual life*	Range (number of aphid consumed)
Larval duration (days)		
1st instar	14.12±2.73	8-22
2nd instar	29.18±3.58	18-45
3rd instar	33.49±2.10	25-48
4th instar	79.81±4.34	52-106
Total larval duration	156.60±5.82	114-198
Adult		
Male	336.01±74.40	84-612
Female	496.44±58.43	98-832
Aphid consumed during life span	572.15±34.47	216-975

* Based on 100 individuals of *Cheilomenes sexmaculata* (Fab.)

Present findings are in agreement with those of Babu (2001) concluded that a grub of *C. sexmaculata* devoured 38.9, 48.4, 68.1, and 92.6 number of *Aphis gossypii* Glover nymph during each larval instars, respectively. Total number of aphids consumed during whole larval duration varied from 114-198 aphids with an average of 156.6 aphids and these were in close conformity with the findings of Eswaramoorthy *et al.* (1998) on sugarcane aphid. However, differed from those of Varma et *al.* (1993), who reported that larva consumed 598.5 *Aphis gossypii* in its lifetime. The gradual increase in the feeding rate of older instars exhibits increased requirement of food due to increase in size.

The female beetle consumed more aphids than male. On an average, a male consumed 336.0 aphids ranging from 84-612 aphids, while a female consumed 496.4 aphids ranging from 98-832 aphids during its life period and these were in conformity with the findings of Eswaramoorthy et *al.* (1998). Contrary to the above findings Varma *et al.* (1993) indicated that a female consumed 277.1 *Aphis gossypii* per day compared with 208.2 aphids by a male. These variations in feeding potential of larvae and adults might be due to different aphid host and prevailing weather conditions of particular area.

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J. Oilseeds Res., **23**(2) : 263-266 (2006)

Evaluation of integrated pest management module against insect pests of sunflower, *Helianthus annuus* L.

K.S. Jagadish, Y.G. Shadakshari, K.T. Puttarangaswamy, Nagaraju and D.P. Jagannatha

All India Coordinated Research Project (Sunflower), University of Agril. Sciences, GKVK, Bangalore-560 065, Karnataka

(Received: May, 2005; Revised: December, 2005; Accepted: December, 2005)

Abstract

Field trials were conducted at Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bangalore during *kharif* seasons of 2003-04 and 2004-05 to evaluate the efficacy of an IPM module against major insect pests of Sunflower. During both the years, the IPM module comprising of imidacloprid @ 5g/kg seed treatment + two sprays of NSKE 5% + two sprays of HaNPV @ 250 LE/ha led to a statistically significant decrease in the population of leafhopper, thrips, aphids and defoliators as compared to the insecticidal check and untreated control. In addition, a higher incidence of predators, lower incidence of *Helicoverpa armigera* Hubner and highest grain yield was also obtained in IPM module, which demonstrated its superiority over chemical control during both the years.

Key words: IPM module, sunflower pests, seed treatment, NSKE and HaNPV

Introduction

Sunflower is an oilseed crop cultivated extensively in India with Karnataka alone accounting for a large share of more than 10 lakh ha. However, the crop is plagued by a wide range of insect pests, which is one of the prime reasons for the low productivity of sunflower. More than, 251 species of insect pests have been identified on this crop world-wide of which about 50 species have been reported in India alone (Rajamohan, 1973).

In Karnataka, leafhopper (*Amrasca biguttula biguttula* Ishida) and thrips have assumed serious dimensions on sunflower. Of late, *Thrips palmi* Karny has been recognized as the vector of the deadly necrosis virus disease. Moreover defoliators *viz.*, *Spilarctia obliqua* Walker, *Spodoptera litura* (Fab.), *Thysanoplusia orichalcea* Fab., *Trichoplusia ni* Hub. and capitulum borer, *Helicoverpa armigera* Hubner are the other major pests (Jagadish *et al.*, 2003).

The attractiveness of sunflower crop invites several species of beneficial species *viz.*, predatory fauna and pollinators particularly honeybees, therefore any pest management technology needs to be focused on the conservation of beneficial fauna which is facilitated by IPM (Lingappa *et al.*, 2003).

The present paper throws light on the results of the field trials conducted to evaluate the efficacy of an IPM module against major pests of sunflower.

Material and methods

The field investigations were conducted during two years i.e., 2003-04 and 2004-05 during *kharif* season. During both the years the plot size, treatments imposed and the design of the experiment (Randomized Complete Block Design) was identical. The plot size was 100 m^2 for each treatment, which was replicated thrice. During *kharif*, 2003, the IPM module (M_1) comprised of seed treatment with imidacloprid 70WS @ 5 g/kg seeds, followed by foliar spray with NSKE 5% applied twice [1st at 37th days after sowing (DAS) and 2nd application at 72 DAS] and two applications of Ha NPV (1st at 60 DAS and second at 72 DAS). During *kharif*, 2004, the same IPM components were applied as follows, pre-sowing seed treatment with imidacloprid 70WS @ 5g/kg seeds, followed by 2 foliar sprays of NSKE 5% (@ 40 and 55 DAS) and 2 applications of Ha NPV (@55 and 65 DAS).

The second treatment *viz.*, insecticidal check (M_2) comprised of foliar sprays of imidacloprid 200 SL @ 0.3 ml/l along with endosulphan 35 EC @ 2 ml/l applied first at 37th DAS and second application of the same two chemicals at 72nd DAS during *kharif*, 2003. However, during *kharif*, 2004 under M_2, imidacloprid 200 SL @ 2 ml/lit. was applied at 40th and 55th DAS, whereas endosulphan 35EC @ 2ml/l was applied at 55th and 65th DAS.

Imposition of the treatments was based on the attainment of economic threshold level (ETL) by the major pests, during both the years.

Observations were recorded by counting the number of sucking insects in 6 leaves/plant, in 10 randomly selected plants/plot. Besides, the incidence of lepidopteran larvae (i.e., defoliators and capitulum borer) was also counted in 10 randomly selected plants. Observations were made one day before imposition of treatments (P_1) and one day after imposition of the treatments (P_2).

The data of both the trials was subjected to statistical analysis under two factor RCBD *viz.*, treatments (M_1, M_2 and M_3), observation period (P_1 and P_2) and the interaction between treatments and observation period (M×P).

Further, the reduction in the population of different pests of sunflower due to imposition of IPM and the chemical treatment was calculated by using the modified Abbot's formula as suggested by Cunnigham (1982). Finally the cost-benefit ratio due to the pest management intervention in the form of IPM and chemical control was calculated for comparison between the two.

Results and discussion

The results of the two trials conducted, once in *kharif*, 2003 and repeated again during *kharif*, 2004 have been subjected to statistical analysis separately and the mean of the two has been calculated and presented in Tables 1-3 and discussed in the following paragraphs.

Impact of IPM on sunflower pests during *kharif*, 2003: Due to IPM intervention (M_1) there was a statistically significant decline in the defoliator population/plant from 0.85 to 0.37; similar decline was observed in leafhopper population from 0.52 to 0.28; that of thrips declined from 4.42 to 1.47; that of aphids declined from 4.37 to 0.51, however, the population of predatory fauna (*Cheilomenes sexmaculata* Fab., *Chrysoperla carnea* Steph and spiders) increased from 0.28 to 0.90 in the IPM module (Tables 1 and 2). Further, the population of *Helicoverpa armigera* (0.54/plant) was least and grain yield (2838 kg/ha) was maximum in IPM as compared to the insecticidal check and untreated control (Tables 2 and 3).

Impact of IPM on sunflower pests during *kharif*, 2004: During 2004 also, IPM intervention caused a significant decline in the population of defoliators (from 2.37 to 0.53/plant) and leaf damage (from 11.67 to 7.94%) (Table 1), whereas, IPM was safer to predatory fauna by recording an increase in their population from 0.00 to 0.17/plant (Table 2). IPM module also recorded lowest incidence of Helicoverpa armigera (0.16/plant) besides registering highest grain yield (2733 kg/ha).

Overall impact of IPM on sunflower pest complex and cost benefit analysis: The critical perusal of the mean of both the years has clearly demonstrated that IPM was significantly superior in reducing the incidence of defoliators, defoliator damage and *H. armigera* load besides, enhancing the population of predators and grain yield.

IPM resulted in the reduction of leafhopper by 83.48%, thrips by 61.63%, aphids by 81.09%, defoliators by 75.79% and *Helicoverpa* by 56.25%. Further, IPM resulted in an increase in the population of predators by 239.79% and grain yield by 17.96%. However, chemical control was superior than IPM in reducing the population of thrips (81.99 %) and aphids (90.90%) (Table 3). The cost benefit ratio was also higher in IPM (1:2.32) as compared to chemical control (1:1.53) (Table 4).

Table 1 Comparison of IPM module against defoliators of sunflower

Treatment (M)	No of defoliators/plant		Mean	Leaf damage (%)
	2003	2004		2004
M_1	0.61 (1.04)	1.45 (1.34)	1.03	9.80 (18.03)
M_2	0.59 (1.02)	1.19 (1.22)	0.89	9.25 (17.62)
M_3	0.75 (1.09)	1.60 (1.44)	1.18	9.50 (17.87)
SEm±	(0.07)	(0.03)	-	(NS)
CD (P=0.05)	(0.22)	(0.10)	-	(NS)
Observation period(P)				
Before treatment (P_1)	0.61 (1.03)	2.12 (1.61)	1.37	9.88 (18.22)
After treatment (P_2)	0.69 (1.07)	0.70 (1.06)	0.69	9.16 (17.45)
SEm±	(0.05)	(0.02)	-	(NS)
CD (P=0.05)	(0.18)	(0.08)	-	(NS)
Interaction (M x P)				
$M_1 P_1$	0.85 (1.16)	2.37 (1.69)	1.61	11.67 (19.95)
$M_2 P_1$	0.56 (1.01)	2.22 (1.64)	1.39	10.11 (18.46)
$M_3 P_1$	0.42 (0.93)	1.78 (1.50)	1.10	7.86 (16.25)
$M_1 P_2$	0.37 (0.92)	0.53 (1.00)	0.45	7.94 (16.11)
$M_2 P_2$	0.61 (1.03)	0.16 (0.80)	0.39	8.40 (16.78)
$M_3 P_2$	1.09 (1.25)	1.42 (1.38)	1.26	11.14 (19.48)
SEm±	(0.10)	(0.04)	-	(1.22)
CD (P=0.05)	(0.31)	(0.14)	-	(3.86)
CV %	(16.37)	(6.04)	-	(11.92)

M_1 : IPM module (imidacloprid 70 WS @ 5 g/kg seed treatment + 5% NSKE + Ha NPV @ 250 LE/Ha
M_2: Imidacloprid 200 SL @ 0.3 ml/lit + endosulphan @ 2ml/lit.
M_3: Untreated control
Figures in parentheses indicate transformed values (√x+0.5 and arcsin)
Defoliation was negligible during 2003, hence, it was not considered for statistical analysis.

Table 2 Comparison of IPM module against sucking pests, *Helicoverpa* and their predators

Treatment (M)	Mean number of insects/plant								
	Leaf hopper*	Thrips*	Aphids*	No. of predators/plant			No. of *Helicoverpa*/plant		
	2003	2003	2003	2003	2004	Mean	2003	2004	Mean
M_1	0.40 (0.94)	2.94 (1.80)	2.44 (1.59)	0.57 (1.01)	0.08 (0.76)	0.33	0.54	0.16	0.35
M_2	0.23 (0.84)	2.44 (1.60)	3.49 (1.76)	0.49 (0.98)	0.13 (0.79)	0.31	0.70	0.43	0.57
M_3	0.49 (0.99)	3.99 (2.10)	3.61 (1.99)	0.57 (1.02)	0.22 (0.84)	0.40	0.74	0.86	0.80
SEm±	(0.02)	(0.09)	(0.16)	(0.04)	(0.03)	-	-	-	-
CD (P=0.05)	(0.06)	(0.39)	(0.50)	(0.14)	(0.10)	-	-	-	-
Observation period (P)									
Before treatment (P_1)	0.28 (0.87)	4.31 (2.17)	5.15 (2.33)	0.50 (0.98)	0.11 (0.77)	0.31	-	-	-
After treatment (P_2)	0.47 (0.97)	1.95 (1.50)	1.21 (1.23)	0.58 (1.02)	0.18 (0.81)	0.38	-	-	-
SEm±	(0.02)	(0.08)	(0.13)	(0.03)	(0.02)	-	-	-	-
CD (P=0.05)	(0.06)	(0.24)	(0.41)	(0.11)	(0.08)	-	-	-	-
Interaction (M x P)									
M_1P_1	0.52 (1.00)	4.42 (3.20)	4.37 (2.19)	0.28 (0.85)	0.00 (0.70)	0.14	-	-	-
M_1P_2	0.09 (0.76)	4.23 (2.14)	6.61 (2.60)	0.66 (1.07)	0.21 (0.83)	0.44	-	-	-
M_2P_1	0.23 (0.85)	4.28 (2.17)	4.47 (2.20)	0.61 (1.04)	0.13 (0.78)	0.37	-	-	-
M_2P_2	0.28 (0.88)	1.47 (1.39)	0.51 (0.99)	0.90 (1.18)	0.17 (0.81)	0.54	-	-	-
M_3P_1	0.37 (0.93)	0.66 (1.06)	0.37 (0.92)	0.32 (0.90)	0.06 (0.74)	0.19	-	-	-
M_3P_2	0.75 (1.12)	3.71 (2.04)	2.76 (1.78)	0.52 (1.00)	0.31 (0.89)	0.42	-	-	-
SEm±	(0.03)	(0.13)	(0.22)	(0.06)	(0.04)	-	-	-	-
CD (P=0.05)	(0.09)	(0.41)	(0.71)	(0.19)	(0.14)	-	-	-	-
CV %	(5.82)	(12.45)	(21.96)	(10.84)	(9.85)	-	-	-	-

M_1 : IPM module (imidacloprid 70 WS @ 5 g/kg seed treatment + 5% NSKE + Ha NPV @ 250 LE/Ha
M_2: Imidacloprid 200 SL @ 0.3 ml/lit + endosulphan @ 2ml/lit.
M_3: *Untreated control*
Figures in parentheses indicate transformed values (√x+0.5 and arcsin)
Defoliation was negligible during 2003, hence, it was not considered for statistical analysis.
* = *Incidence of sucking pests was very negligible in 2004; hence, it was not considered for statistical* **analysis**

Table 3 Percentage change* in pest and predator populations due to treatments

Treatment	*Leaf hopper**	*Thrips**	*Aphids**	*Defoliators**	*% leaf damage**	*Predators**	*Helicoverpa**	*Grain yield**
IPM module	83.48 ↓	61.63 ↓	81.09 ↓	75.59 ↓	51.99 ↓	239.79 ↑	56.25 ↓	17.96 ↑
Chemical control	26.07 ↑	81.99 ↓	90.90 ↓	75.50 ↓	41.37 ↓	61.95 ↓	28.75 ↓	7.57 ↑

↓ : Per cent reduction over untreated check
↑ : Per cent increase
* : Computation based on modified Abbot's formula (Cunningham, 1982)
+ : Per cent change over untreated check

Table 4 Comparison of cost-benefit ratio due to different treatments

Treatment	Yield* (kg/ha)	% yield increase over control	Additional yield over control	Cost of treatment (Rs.)	Value of additional yield (Rs.)	C : B ratio
IPM module	2759	17.96	421	3075	7157	1 : 2.32
Chemical control	2515	7.57	177	1960	3009	1 : 1.53
Untreated control	2338	-	-	-	-	-

* Average yield of 2003 and 2004

One of the components of the superior IPM module tested in the present investigations i.e., seed treatment with imidacloprid @ 5g/kg seed has been successfully used in combating the seedlings pest of sunflower viz., cutworm, *Agrotis ipsilon* by Bakhetia and Arora (1995). Further, the present findings have proved beyond doubt, that integration of two or more pest management components into the IPM module, is a step in the right direction for effective suppression of insect pests of sunflower, besides safeguarding the predatory fauna, which are abundantly available in sunflower eco-system as indicated by Goel and Kumar (1990), these natural enemies, by themselves will exercise a strong check on the buildup of sunflower pests, if application of chemical insecticides are minimized.

It is needless to say that, there is an ample scope for the deployment of Integrated Pest Management Module (IPM) in sunflower, which is not only economically viable but also eco-friendly.

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J. Oilseeds Res., **23**(2) : 267-269 (2006)

Relationship between thrips population, sunflower necrosis disease (SND) incidence and weather parameters

S. Upendhar, T.V.K. Singh and R.D.V.J. Prasada Rao

Dept. of Entomology, College of Agriculture, A.N.G. Ranga Agril. University, Rajendranagar, Hyderabad-500 030, AP

(Received: October, 2005; Revised: February, 2006; Accepted: June, 2006)

Abstract

Sunflower, *Helianthus annuus* L. necrosis caused by tobacco streak virus is transmitted by thrips in the presence of infected pollen. In order to understand the fluctuations of thrips population and disease incidence during different seasons, different dates of sowing were taken up from August, 2003 to March, 2004. The incidence of the disease ranged from 16.8% to 62.8% with highest in *kharif* months (August - 35.0%, September - 49.9%), low during *rabi* months (October - 20.8%, November - 28.7%) moderate during summer months (January 26.2%, February 30.4% and March 25.0%). Further, the thrips population/head varied from 4.8 to 16.4 thrips/head with not much variation among seasons except on rainy days/week. There was a positive correlation of thrips population with maximum temperature and negative correlation with minimum temperature, RH (morning and evening) and rainfall. Disease incidence showed positive correlation with minimum temperature, RH (morning and evening) and rain fall, but negative correlation with maximum temperature. Further, there was a clear positive correlation between thrips population and sunflower necrosis disease incidence.

Key words: Sunflower, tobacco streak ilarvirus, thrips

Introduction

Sunflower is a promising oilseed crop in the country next to groundnut and soybean. Sunflower, introduced into India during 1969, accounts for nearly 5% of the current oilseed production. In Andhra Pradesh, sunflower occupies an area of about 1.97 lakh ha with a production of 1.68 lakh tones with an average yield of 853 kg/ha in 2000-01.

In recent years, sunflower cultivation has been seriously hampered by necrosis disease (SND). The disease was observed for the first time during 1997 at Bagepally near Bangalore (Karnataka) (Singh *et al.*, 1997), which later spread to the neighbouring states of Andhra Pradesh, Tamil Nadu and Maharashtra posing a serious threat to sunflower cultivation.

The causal virus of the disease has been identified as tobacco streak ilarvirus and shown to be transmitted by thrips in the presence of infected pollen grains (Ravi *et al.*, 2001; Reddy *et al.*, 2002). The surveys conducted during 1998-2001 by Directorate of Oilseeds Research, Hyderabad revealed that the disease was widespread and intensity ranged from 2-100%. The disease caused severe epidemics at some places resulting in total yield loss. In general, the disease incidence was erratic and its incidence varied from season to season, year to year and place to place. The present studies were undertaken to find out the relationship among thrips population, incidence of necrosis disease and weather parameters.

Material and methods

Sunflower cultivar Morden was sown at monthly intervals from August, 2003, upto March, 2004 in a plot size of 500 sq. m. (25 m x 20 m) at College Farm, College of Agriculture, Rajendranagar, Hyderabad. There were three replications (25 m x 6.67 m) with 60 x 30 cm spacing.

The thrips population and SND incidence was regularly observed on 5 sq. m. selected area in each replication (1 sq. m. area from each corner of field and 1 sq. m. from center) at weekly interval (standard meteorolysed). In each 1 sq. m. area one plant at random was selected and the head was bent aside and three strokes were given. The dislodged thrips were counted and transferred to 70% alcohol for identification (Bullock, 1963).

The data on maximum and minimum temperature (°C), relative humidity at morning (RH-I) and evening (RH-II) and rainfall (mm) corresponding to the standard meteorological weeks and crop period were collected from Meteorological Observatory located at CCS Agricultural Research Institute, Rajendranagar, Hyderabad. Correlation matrix was drawn for the thrips population and weather parameters, SND and weather parameters. Further, correlation matrix was also drawn between the thrips population and SND incidence in the field.

Results and discussion

Five species of thrips, *Thrips palmi* (Karny), *Frankliniella schultzei* (Trybom), *Scirtothrips dorsalis* (Hood), *Megalurothrips usitatus* (Bagnall) and *Haplothrips gowdeyi* (Franklin) were identified following the keys of Reddy *et al.* (1991) and Palmer *et al.* (1992).

The average thrips population/head recorded at weekly interval ranged from 4.8 to 16.4 over different sowing dates, in different seasons (Table 1). However, the average number of thrips/head decreased during rainy weeks. The higher average thrips/head of 12.9 was was recorded during August and lowest 8.9 thrips/head was recorded during September .The per cent incidence of necrosis disease recorded at weekly intervals ranged from 16.8% to 62.8% (Table 1).

The disease was high during August 35.0% and September 49.9% corresponding with highest thrips population/head in August. The disease incidence was low during *rabi* months (October 20.8%, November 28.76%, December 20.3%) corresponding with the declining thrips population during September, October, November months. The disease incidence was moderate during January 26.2%, February 30.4% and March 25.0% (Table 1) with moderate thrips population during December, January and February.

The overall correlation matrices drawn for thrips population and weather parameters, disease incidence and weather parameters, thrips population with disease incidence are presented in the Table 2a, 2b and 2c.

There was a positive correlation of thrips population with maximum temperature and negative correlation with minimum temperature, RH-I, RH-II and rainfall which indicates the involvement of these parameters in fluctuation of the population of the vector during different seasons. There was a positive correlation of SND with minimum temperature, RH-I, RH-II and rainfall but negative correlation with maximum temperature indicating the involvement of all these factors in fluctuations in the incidence of the disease during different seasons further indicating high maximum temperature was not congenial for spread of the disease.

The overall results showed that the weather parameters like maximum temperature favour the build up of thrips population and their activity resulting in the spread of this disease. On the other hand, relative humidity, minimum temperature and rainfall affect the thrips and vector activity in the field negatively, thus, playing an important role in reducing the incidence of this disease under natural conditions.

Table 1 Monthly average of thrips population/head and per cent SND incidence during crop period of sunflower (August, 2003 to March, 2004)

Month	Monthly average thrips population/head	Monthly average incidence of SND (%)
August, 2003	13	35
September, 2003	9	49.9
October, 2003	11	20.8
November, 2003	11	28.6
December, 2003	13	20.3
January, 2004	12	26.2
February, 2004	11	30.4
March, 2004	11	25.0

Table 2a Overall correlation matrix of thrips population/head with weather parameters

	Temp. (Max.)	Temp. (Min.)	RH-I	RH-II	Rainfall (mm)	Thrips population
Temp.(Max.)	1.0000					
Temp. (Min.)	0.6267**	1.0000				
RH-I	-0.8271**	-0.3545*	1.0000			
RH-II	-0.5378**	0.2519	0.6954**	1.0000		
Rainfall (mm)	0.0234	0.2718	0.2308	0.3327*	1.0000	
Thrips population	0.0779	-0.0001	-0.0922	-0.0779	-0.0597	1.0000

Table 2b Overall correlation matrix of per cent sunflower necrosis disease with weather parameters

	Temp. (Max.)	Temp. (Min.)	RH-I	RH-II	Rainfall (mm)	Thrips population
Temp.(Max.)	1.0000					
Temp.(Min.)	0.6267**	1.0000				
RH-I	-0.8271**	-0.3545*	1.0000			
RH-II	-0.5378**	0.2519	0.6954**	1.0000		
Rainfall (mm)	0.0234	0.2718	0.2308	0.3327*	1.0000	
Thrips population	-0.1243	0.1793	0.2516	0.3212*	0.2108	1.0000

Table 2c Overall correlation matrix of thrips population and per cent SND

	Thrips population	% SND
Thrips population	1.0000	
% SND	0.0393	1.0000

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

However, a similar study by Shivasharanayya and Nagaraju (2003) explained. Successful correlation between thrips population, SND incidence and weather factors and this was the first successful correlation study of SND with thrips population and environment factors.

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J. Oilseeds Res., **23**(2) : 270-272 (2006)

An integrated approach for the management of budfly *Dasyneura lini* Barnes and blight (*Alternaria lini* Dey) in Linseed, *Linum usitatissimum* L.

M.P. Gupta

College of Agriculture, J.N. Krishi Vishwa Vidyalaya, Tikamgarh-472 001, MP

(Received: July, 2005; Revised: May, 2006; Accepted: June, 2006)

Abstract

Effect of dates of sowing, intercropping, neem formulation and insecticide was studied against budfly (*Dasyneura lini* Barnes) and bud blight (*Alternaria lini* Dey) in linseed at JNKVV, College of Agriculture, Tikamgarh (M.P.) during *rabi* 2001-02 and 2002-03. The results indicated that linseed crop sown during end of October had significantly lower damage of budfly and blight with higher seed yield as compared to late sown crop (3rd week of November). The linseed crop sown as sole crop observed higher incidence of budfly and lower yield as compared to linseed intercropped with chickpea. Incidence of both the pests was significantly managed and higher grain yields were obtained with the foliar spray of neem seed kernel extract (in cow urine) 3% followed by neem oil 1% and dimethoate 0.04%. Linseed equivalent yield was further increased with the intercropping of mustard/chickpea (in 3:1 row ratio).

Key words: Linseed, *Dasyneura lini, Alternaria lini,* management

Introduction

Linseed, *Linum usitatissimum* Linn. is an important *rabi* oilseed crop of Madhya Pradesh but has very low yield of 250 kg/ha as compared to 350 kg/ha as national average and 600 kg/ha of world average. Among the biotic constraints responsible for low yield of linseed, damage due to budfly (*Dasyneura lini* Barnes) and blight (*Alternaria lini* Dey) are of utmost importance. Several insecticides have been tried in the past, but, due to low economics and toxic residues in seeds are not commonly used by farmers. Application of botanicals is very meager on this crop.

Planting date of linseed also plays an important role in managing the incidence of budfly (Singh *et al.*, 1991) and the incidence of insect pests is reduced in intercropping systems as compared to monoculture (Gangwar *et al.*,1994). Keeping these facts in view, an attempt has been made to study the integrated effect of date of sowing, cropping system and botanicals on the incidence of budfly and *Alternaria* blight.

Material and methods

The experiment was laid out in Split Plot Design during two consecutive *rabi* seasons of 2001-02 and 2002-03. Treatments at main plot were two dates of sowing *viz*, D_1-31st October and D_2-17-23, November, at subplot three cropping systems *viz*., Linseed+Mustard (3:1 row ratio), Linseed + chickpea (3:1 row ratio) and Linseed as alone and at sub-sub plot four treatments were applied as foliar spray, T_1- Neem oil-1%, T_2- Neem seed kernel extract (in cow urine)- 30 ml/l, T_3-Dimethoate-0.04% and T_4-Untreated. Keeping in view, the level of incidence during 2001-02, no foliar spray was applied in D_1 sown crop and only single spray was applied in D_2 sown crop (22-01-2002). Where as, during second year of study, one spray was given in D_1 (07-01-2003) and 2 sprays in D_2 sown crop (23-01-2003 and 07-02-2003).

Plot size was kept 3 m x 3.6 m with 30 cm row spacing in each cropping system. JLT-26 variety of linseed, JG-322 of chickpea and Varuna of mustard were sown in the experiment as per the treatments. The trial was replicated thrice and recommended doses of fertilizers were applied.

Neem seed kernel extract in cow urine was prepared by soaking 100 gm crushed neem kernels in one litre of cow urine, for 10-15 days and then filtering the extract. In neem preparations liquid detergent soap 'ezee' was mixed @ 0.5 ml/l of spray solution.

Observations on the incidence of budfly were recorded as per the standard method of AICRP on linseed at bud stage and dough stage and of *Alternaria* blight only at dough stage by counting healthy and infected buds/capsules of five plants selected randomly.

Results and discussion

Effect of dates of sowing on the incidence of budfly, blight and grain yield: Date of planting showed a great impact on the incidence of budfly and blight being significantly lower in the crop sown on 31st October as compared to 3rd week of November during both seasons and in pooled mean (Table 1). Grain yield was also

obtained significantly higher in early sown crop during both years and in mean values. Similar impact of dates of sowing on incidence of budfly as well as on grain yield in linseed was reported by Pal *et al.*(1978) and Singh *et al.* (1991).

Effect of intercropping: Mean incidence of bud fly and blight in two years varied significantly in different cropping systems and was lowest in the linseed crop when intercropped with chickpea and was highest when intercropped with mustard (Table 2). Higher incidence of budfly and blight in linseed+mustard intercropping system might be due to higher relative humidity caused by profuse growth of mustard crop, particularly, during later season of study.

Linseed equivalent grain yield was minimum in linseed crop sown as alone and was significantly higher in linseed+mustard cropping system followed by linseed+chickpea during both seasons and in pooled mean.

Efficacy of neem products: Incidence of budfly was minimum in dimethoate treated plots but not significantly different from neem oil and NSKE treated plots, thus, all the three treatments being at par in managing the budfly incidence (Table 1 and 2). Whereas, infestation of blight was minimum in neem seed kernel extract treated plots during both years.

Grain yield was significantly higher in treated plots as compared to untreated being almost equal in all the three treatments, NSKE, neem oil and dimethoate. Similar higher grain yield in linseed crop by controlling the incidence of budfly with neem products have been reported by Gupta *et al.*(2000) and Gupta and Rawat (2004).

Table 1 Impact of IPM factors on the incidence of budfly, bud blight and grain yield (2001-02 and 2002-03)

Dates of sowing	% capsule damage at harvest						Linseed equivalent yield (kg/ha)		
	Due to budfly			Due to *Alternaria*					
	2001-02	2002-03	Mean	2001-02	2002-03	Mean	2001-02	2002-03	Mean
Effect of dates of sowing									
D_1 - 31st October	1.3 (5.6)	7.5 (15.7)	4.4 (10.7)	1.6 (6.9)	5.9 (13.8)	3.7 (10.3)	1659	2358	2009
D_2 - 3rd week of November	*4.2* (10.9)	*30.3* (28.4)	*17.3* (19.7)	*3.0* (9.3)	*12.2* (20.1)	*7.6* (14.7)	*1428*	*2109*	*1769*
SEm±	0.8	1.0	0.8	0.7	0.6	0.6	26	40	30
LSD (P=0.05)	2.4	2.8	2.3	2.0	1.6	1.6	75	118	88
Effect of intercropping system									
1 - Linseed+Mustard (3:1)	2.2 (6.5)	21.7 (26.1)	12.0 (16.2)	2.4 (8.0)	12.6 (20.3)	7.5 (14.1)	1678	2533	2105
2 - Linseed + Chickpea (3:1)	2.5 (8.1)	11.6 (19.4)	7.0 (13.8)	2.2 (7.8)	6.7 (14.7)	4.4 (11.3)	1595	2250	1923
3 - Linseed	3.6 (10.3)	12.9 (20.6)	8.2 (15.5)	2.3 (8.5)	7.9 (15.9)	5.1 (12.2)	1350	1918	1634
SEm±	0.7	1.0	0.6	0.7	0.5	0.5	27	47	30
LSD (P=0.05)	2.2	3.0	1.7	NS	1.6	1.5	79	138	88
Effect of neem products									
T_1 - Neem oil (1%)	1.8 (6.8)	14.2 (21.0)	8.0 (13.9)	2.0 (7.5)	8.7 (16.6)	5.4 (12.1)	1600	2317	1959
T_2 - NSKE 3% (in cow urine)	2.6 (8.4)	13.3 (20.6)	8.0 (14.5)	1.7 (7.0)	8.1 (16.0)	4.9 (11.5)	1554	2405	1980
T_3 - Dimethoate (0.04%)	1.6 (6.3)	13.4 (20.4)	7.5 (13.4)	1.8 (7.4)	8.7 (16.8)	5.3 (12.1)	1600	2333	1967
T4 - Untreated	5.0 (11.4)	20.8 (26.3)	12.9 (18.8)	3.8 (10.4)	10.5 (18.5)	7.1 (14.5)	1419	1856	1638
SEm±	1.0	0.4	0.6	0.8	0.4	0.5	35	55	38
LSD (P=0.05)	2.9	1.2	1.7	2.4	1.2	1.5	102	159	110

Figures in parenthesis are transformed values arc sin √p

Table 2 **Mean interaction effect of dates of sowing, cropping systems and neem products on the incidence of budfly and blight and grain yield of linseed (2001-02 and 2002-03)**

Cropping system	D_1 (31st October)				D_2 (3rd week of November)			
	Neem oil (1%)	NSKE 3%	Dimethoate 0.04%	Untreated	Neem oil (1%)	NSKE (%)	Dimethoate 0.04%	Untreated
% capsule damage due to bud blight								
Linseed + Mustard	4.2 (11.0)	4.1 (11.0)	4.0 (10.4)	4.6 (11.0)	11.1 (18.3)	9.6 (16.5)	9.5 (16.0)	13.1 (20.6)
Linseed + Chickpea	2.7 (7.0)	2.5 (8.6)	3.8 (11.1)	4.4 (11.8)	5.2 (12.6)	4.9 (11.7)	5.3 (12.9)	7.0 (15.2)
Linseed alone	3.3 (10.3)	3.0 (9.6)	3.9 (11.1)	4.9 (12.3)	5.9 (12.9)	5.7 (13.3)	4.6 (11.0)	9.0 (17.1)
CS x Neem products SEm±			1.0				1.2	
LSD (P=0.05)			2.9				3.5	
% capsule damage due to budfly								
Linseed + Mustard	3.0 (7.0)	3.5 (9.3)	3.3 (9.4)	5.4 (11.0)	19.9 (23.7)	16.3 (21.5)	16.4 (19.7)	28.6 (30.7)
Linseed + Chickpea	3.4 (9.1)	4.1 (11.2)	3.5 (10.4)	6.4 (12.3)	8.9 (16.5)	10.0 (17.7)	7.4 (12.7)	14.0 (21.1)
Linseed alone	4.6 (12.0)	5.0 (12.5)	4.5 (11.5)	7.1 (14.5)	8.6 (15.2)	9.2 (16.6)	10.0 (17.7)	17.1 (24.0)
CS x Neem products SEm±			1.1				1.3	
LSD (P=0.05)			3.2				3.8	
Linseed equivalent grain yield kg/ha and economics								
Linseed + Mustard	2281	2403	2239	2131	2054	2073	2035	1652
Linseed + Chickpea	2117	2035	2064	1844	1975	1829	1995	1452
Linseed alone	1753	1818	1880	1537	1642	1671	1567	1211
Mean	2050	2085	2061	1837	1890	1858	1866	1438
Net profit (Rs/ha)	2842	3387	3021	-	5908	5625	5647	-
B:C ratio	21.3	40.8	27.3	-	15.1	23.0	17.4	-
CS x Neem products SEm±			35				41	
LSD (P=0.05)			103				120	

Figures in parenthesis are transformed values are Sin √p

Effect of interaction of date of sowing, cropping system and neem products: The incidence of budfly and bud blight was reduced to minimum in D_1 sown crop of linseed when intercropped with mustard/chickpea and treated either with neem oil, NSKE or dimethoate 0.04%. Whereas, linseed equivalent grain yield was maximum (2403 kg/ha) in D_1 sown linseed crop intercropped with mustard and treated with NSKE 3% followed by linseed+mustard treated with neem oil 1% (2281 kg/ha) and linseed+mustard treated with dimethoate 0.04% (2239 kg/ha) as compared to only 1211 kg/ha in D_2 sown linseed crop grown alone as untreated (Table 1 and 2). The higher yield in early sown linseed crop following intercropping system either with mustard or gram and treated with neem seed kernel extract/neem oil might be due to lower incidence of pests along with the better crop growing regimes in these treatments.

Economics of treatments: Maximum net profit and B:C ratio in D_1 sown crop was obtained with NSKE 3% (Rs.3387/ha and 40.8) followed by dimethoate 0.04%. Whereas, in D_2 sown crop, highest net profit was gained with neem oil 1% but, B:C ratio was maximum with NSKE 3% (Table 2).

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J. Oilseeds Res., **23**(2) : 273-276 (2006)

Effect of shading on growth, yield and disease development of Indian mustard, *Brassica juncea* (L.) Czern & Coss

Lallu and Rajendra Prasad

Oilseed Section, C.S. Azad University of Agriculture & Technology, Kanpur-208 002, UP

(Received: May, 2005; Revised: December, 2005; Accepted: December, 2005)

Abstract

***Effect of 25 and 50% shading along with control* (without shade) at three stages viz., 30-50DAS (early flowering stage), 51-70DAS (active flowering stage) and 71-90DAS (post flowering stage) on mustard, *Brassica juncea* (L) Czern & Coss was studied. Shade either of two levels given at any stage increased plant height and disease intensity of *Alternaria* blight and powdery mildew but decreased number of branches, dry matter production, SLW, CGR and NAR. Increasing level of shade decreased number of siliquae/plant, seeds number/siliqua, 1000 seed weight, seed yield and harvest index 50% shading proved more deleterious than 25% shading given at any stage of plant growth. Plants at active flowering stage (51-70DAS) exposed under 50% shading proved more sensitive than other two stages tried and drastic reduction occurred in the aforesaid characters.**

Key words: Mustard, shading, SLW, CGR, NAR, disease intensity

Introduction

Solar radiation the source of light energy is the main input of the photosynthetic process for the green plants. Under low light intensity dry matter production is impaired due to low rate of photosynthesis. Yield of beans (Crookston *et al.*, 1975), peanut (Hang *et al.*, 1984), wheat (Savin and Salfer, 1991) and rice (Singh, 1994) decreased under low light intensity created by artificial shading. Such information is rather lacking on the effect of low light intensity on mustard crop. Therefore, an attempt was made to study the effect of different levels of light intensity created by artificial shading on growth and yield of mustard crop.

Material and methods

A field experiment was conducted with Indian mustard cultivar, Varuna at Oilseed Research Farm, Kalyanpur, C.S.A. University of Agriculture and Technology, Kanpur during *rabi*, 2002-03 and 2003-04 in a Randomized Block Design with three replications. Crop was sown with 45 cm distance between rows and plant spacing was maintained at 15 cm by manual thinning at 20 days after sowing. The recommended dose of fertilizers i.e. 150:75:75 Kg/ha of NPK was applied as half N and full P and K as basal and remaining half N was applied as top dressing. The natural sunlight falling on the crop was reduced to 25 and 50% by covering the plants with synthetic shading nets fixed on iron frame at three stages of plants growth *viz.*, early flowering stage (30-50 DAS), active flowering stage (51-70 DAS) and post flowering stage (71-90 DAS). The control plants were grown under natural sun light throughout from sowing to harvest. Observations on plant height and number of branches were recorded at harvest, while dry matter production was recorded at 20 days interval commencing from 30 days after sowing upto harvest. Various growth parameters such as specific leaf weight (SLW), crop growth rate (CGR) and net assimilation rate (NAR) were computed as described by (Watson, 1952). The seed yield and yield attributes such as number of siliquae/plant, number of seeds/siliqua and 1000 seed weight were recorded at the time of harvest. Harvest index (%) was calculated as 100x (seed yield/biological yield at harvest).

Results and discussion

Plant height, branches, diseases development, yield and yield attributes: Shading of plants did not influence plant height as compared to control during both years given at any stage of plant growth (Table 1). Maximum plant height was recorded when plants exposed under 50% shading at post flowering stage (71-90 DAS) than other shading treatments tried. (Vyas *et al.*,1996; Patra *et al.*, 2003) also reported the increase in plant height under shades of various intensities.

Number of branches and harvest index were more in plants grown under 25% shading than 50% shading given at any stage of plant growth. 50% shading given at active flowering stage (51-70 DAS) produced lowest branches and also value of harvest index during both years (Table 1). Reduction in harvest index due to shading was also reported by (Jadhav *et al.*, 1993; Singh, 1994).

The shading significantly increased the disease incidence of *Alternaria* blight (*Alternaria brassicae*) and powdery

mildew (*Erysiphae cruciferarum*) as compared to control during both years. Significantly highest *Alternaria* blight intensity (68.3%) and Powdery mildew intensity (64.0%) were observed under 50% shading provided at 51-70 DAS (active flowering stage) followed by 25% shading given at same stage, whereas in control it was recorded lowest (Table 1). The higher incidence of diseases under low light intensity may be due to prolong period of maturity. (Das Gupta *et al.*, 1991) has reported that increase in disease intensity and less in yield due to *Alternaria* blight in delayed maturing mustard crop. Prasad and Saxena (2001) also reported the similar finding with regards to powdery mildew of the present study.

Reduction of light either of 25 and 50% at active flowering stage (51-70 DAS) caused considerable decline in yield attributes as well as in seed yield followed by exposure at early flowering stage (30-50 DAS), while at post flowering stage (71-90 DAS) the effect was comparatively less than that seen in earlier two stages (Table 1). 25% shading applied at any stage of growth produced more number of siliquae, number of seeds/siliqua, test weight and seed yield than 50% shading given at any stage of plant growth. 50% shading given at 51-70 DAS stage produced significantly lowest number of siliquae, 1000 seed weight and seed yield during both years. Maximum reduction in seed yield by 27% and 34% occured due to 50% shading followed by 23% and 29% due to 25% shading both given at active flowering stage (51-70DAS) in first and second year respectively as compared to control. Reduction in yield and yield attributes of various crops due to low light stress have been reported by several workers. (Lawson and Koang, 1990), (Perumal and Rao, 1991), (Savin and Salfer, 1991) and (Singh, 1994).

Dry matter and growth parameters: Significant reduction in dry matter acumulation occured as increased in reduction of light intensity as higher produced by the plants enjoyed full natural light, whereas lower was produced by the plants treated with 50% light intensity (Table 2). Early flowering stage (30-50 DAS) with 50% light intensity caused maximum 29% and 36% reduction in drymatter production in first and second year respectively as compared to that grown under full natural light. Reduction in drymatter production may be due to decrease in photosynthetic efficiency decrease in absence of full natural light in this crop.

Table 1 Growth characters, disease intensity, yield and yield attributes as affected by different levels of shading at different stages

Character	Control (no shading)	25% Shading			50% Shading			CD (P=0.05)
		S_1	S_2	S_3	S_1	S_2	S_3	
Plant height (cm)								
2002-03	125.9	12.7.0	131.4	134.2	135.3	135.8	136.9	N.S.
2003-04	122.3	125.2	125.8	132.7	132.3	135.3	136.3	N.S.
No. of branches/plant								
2002-03	18.9	14.3	14.1	15.8	13.0	11.7	16.0	1.4
2003-04	21.2	17.0	15.7	20.5	17.3	14.6	19.1	1.0
Harvest index (%)								
2002-03	20.2	18.0	17.8	19.3	17.7	16.5	18.9	0.8
2003-04	23.3	19.6	18.9	22.7	18.1	17.7	20.0	0.9
***Alternaria* blight (% disease intensity)**								
2002-03	35.0	48.3	55.0	38.3	56.6	68.3	53.3	16.9
2003-04	31.6	36.6	40.0	35.0	36.6	60.0	51.6	13.8
Powdery mildew (% disease intensity)								
2002-03	37.3	45.3	63.3	43.3	55.6	64.0	48.0	13.1
2003-04	36.0	43.0	53.6	38.0	49.3	58.0	38.6	N.S.
No. of siliquae/plant								
2002-03	447.5	413.5	400.4	418.8	330.5	293.2	407.7	55.3
2003-04	462.1	373.3	333.9	382.7	322.1	316.2	377.3	55.8
No. of seeds/siliqua								
2002-03	9.4	9.4	8.1	9.3	8.3	7.9	9.2	N.S.
2003-04	12.5	12.3	11.9	12.5	12.1	11.9	12.3	0.5
1000-seed weight (g)								
2002-03	4.7	4.6	4.2	4.6	4.2	3.9	4.6	0.5
2003-04	5.2	4.7	4.5	4.9	4.7	4.1	4.8	0.3
Seed yield (kg/ha)								
2002-03	1399.3	1193.3	1069.9	1234.6	1053.3	1020.5	1152.1	116.5
2003-04	1629.6	1251.1	1152.3	1481.5	1152.3	1069.9	1316.8	142.9

Stages: S_1-30-50 DAS; S_2-51-70 DAS and S_3-71-90 DAS

Table 2 Dry weight and growth parameters of mustard as affected by different shading levels at different stages

Stage	2002-03				2003-04			
	Control (No shading)	25% Shading	50% Shading	Mean	Control (No shading)	25% Shading	50% Shading	Mean
Dry weight (g)/plant								
S_1	11.4	10.0	8.1	9.8	12.9	8.6	8.2	9.9
S_2	21.6	19.4	17.0	19.3	27.6	22.5	20.5	23.5
S_3	39.2	31.3	28.8	33.1	43.5	38.2	34.1	38.6
Mean	24.0	20.2	17.9		28.0	23.1	20.9	
CD (P=0.05)								
	Stages			2.3				0.87
	Shading			2.3				0.87
	Interaction			N.S.				0.87
SLW (mg/cm^2)								
S_1	6.0	6.0	5.7	5.9	5.8	5.7	5.5	5.6
S_2	8.7	7.8	7.2	7.9	7.8	6.8	6.2	6.9
S_3	8.3	7.7	6.8	7.6	7.8	6.3	5.7	6.6
Mean	7.6	7.1	6.5		7.1	6.2	5.8	
CD (P=0.05)								
	Stages			0.6				0.1
	Shading			0.6				0.1
	Interaction			N.S.				0.2
CGR (g/m^2)/day								
S_1	4.4	3.8	2.8	3.6	7.3	4.3	3.9	5.1
S_2	8.4	7.7	7.0	7.7	10.3	9.7	8.6	9.5
S_3	10.2	8.1	7.5	8.6	11.1	10.9	9.6	10.5
Mean	7.6	6.5	5.7		9.5	8.3	7.3	
CD (P=0.05)								
	Stages			1.6				0.9
	Shading			N.S.				0.9
	Interaction			N.S.				N.S.
NAR (mg/cm^2/day)								
S_1	0.71	0.63	0.48	0.60	0.74	0.59	0.55	0.62
S_2	0.79	0.79	0.78	0.78	0.86	0.83	0.77	0.82
S_3	1.28	0.96	0.96	1.06	1.01	1.03	0.98	1.00
Mean	0.92	0.79	0.74		0.87	0.81	0.76	
CD (P=0.05)								
	Stages			0.22				0.08
	Shading			N.S.				N.S.
	Interaction			0.39				0.14

Stages: S_1-30-50 DAS; S_2-51-70 DAS and S_3-71-90 DAS

The specific leaf weight (SLW) declined with light intensity reduced and it was significantly lower under 50% shading treated plants as compared to control plants (Table 2). Higher value of SLW was recorded at active flowering stage (51-70 DAS) than other two stages tried during both years. Interaction was significant only in the second year. The crop growth rate (CGR) and net assimilation rate (NAR) increased with increase crop age from early flowering (30-50 DAS) upto post flowering stage (71-90 DAS). CGR and NAR both declined with increasing levels of shading only numerically except CGR in the second year of study. Plants received 50% shading displayed minimum value of CGR and NAR during both years. Interaction was significant only in case of NAR, (Crookston et al., 1975; Singh, 1986; Singh *et al.*, 1988) also reported that shading reduced leaf thickness and NAR.

It is concluded that shading caused marked reduction in number of branches, growth indices, yield attributes, harvest index and increased disease intensity which collectively affected the yield. The present study suggest that shading at active flowering stage (51-70 DAS) should be avoided to increase the seed yield of this crop.

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J. Oilseeds Res., **23**(2) : 277-280 (2006)

Genetic architecture of fatty acid profiles in a cross of Indian mustard, *Brassica juncea* (L.) Czern & Coss

J.S. Chauhan, M.K. Tyagi, Poonam Tyagi, Maharaj Singh, Arvind Kumar and N.B. Singh[1]

National Research Centre on Rapeseed-Mustard, Sewar, Bharatpur-321 303, Rajasthan

(Received: February, 2005; Revised: October, 2005; Accepted: December, 2005)

Abstract

Six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of the cross TERI (OE) M 21 x RH 30 of Indian mustard (*Brassica juncea* L.) were analyzed for erucic, oleic and linoleic acid content using gas liquid chromatograph during 1998-99 to study their genetic architecture. The F_1 means for erucic, oleic and linoleic acid were closer to the mid-parent value suggesting partial dominance of gene(s) controlling higher content over low one. The differences in the means of F_1 and reciprocal F_1 for erucic acid content suggested the role of cytoplasm in the genetics of erucic acid. The significance of scaling tests suggested the presence of epistasis in the genetic control of these fatty acids. Additive effects for oleic acid, additive and additive x additive effects for erucic acid were predominant. Linoleic acid appeared to be controlled by both additive x additive and dominance x dominance interactions. Narrow-sense heritability (h^2ns) was high for erucic acid (0.85) and oleic acid (0.63) and low for linoleic acid (0.26). The minimum number of effective factor pairs controlling the genetics of erucic, oleic and linoleic acid were 2, 2 and 5, respectively. The present study suggests that selection for low erucic acid and high oleic acid would be quite effective in early segregating generations, whereas selection for desirable level of linoleic acid should be deferred to advanced generations.

Key words: Fatty acid profiles, genetics, gene effects, mustard, *Brassica juncea*

Introduction

Fatty acid profiles determine the quality of mustard (*Brassica juncea* [L.] Czern. & Coss.) oil, which is an important component of Indian diet. Prevalent mustard varieties yield oil having low (about 7%) saturated fatty acids (palmitic+ stearic acid), high erucic (about 50%), low oleic (9-18%) and linoleic acid (13-25%). The preferred oil should have low saturated fatty acids (around 4%), low erucic acid (<2%) and appreciable amount of unsaturated fatty acids (oleic and linoleic). Low erucic acid © 22:1) and intermediate level of linoleic (C18: 2), an essential fatty acid improve the nutritional quality of the oil and high oleic © 18: 1) imparts thermo stability to the oil and also lowers cholesterol, a major component associated with coronary heart diseases (Grundy, 1986). It is, therefore, imperative to breed mustard varieties with increase level of both oleic (about 50%) and linoleic acid (20-25%) and reduced erucic acid (<2%) to improve its nutritional quality. Genetic enhancement of a character is primarily dependent on its genetic architecture, which ultimately decides the success of the conventional breeding programme. Such information regarding fatty acids in Indian mustard is limited (Tiwari, 1995; Potts and Males, 1999; Chauhan *et al.*, 2002a,b). Therefore, the present investigation were attempted to study genetics of oleic, linoleic and erucic acid in Indian mustard so as to devise appropriate breeding methodology for their improvement.

Material and methods

The materials for the present investigation consisted of the six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of the cross TERI (OE) M 21 x RH 30 of Indian mustard . TERI (OE) M 21) is a low erucic (<2%); relatively high oleic (38.8%) and linoleic acid (42.5%) strain developed at TERI, New Delhi and RH 30 is a high yielding variety, having low oleic (9.6%), low linoleic (16.6%) and high erucic acid (50.5%). These generations were grown in randomized complete block design with two replications during 1998-99 *rabi* season. The rows were 5 m long and spaced 30 cm apart and spacing between plants with-in-a-row was maintained at 10 cm. Each replication comprised one row of P_1, P_2 and F_1 generation, 3 rows for F_2 generation and two rows of BC_1 and BC_2 generations. Standard agronomic practices were followed to raise a good crop. The plants were selfed and selfed seeds were harvested. The number of plants ranged from 10 for P_1, P_2; 10-15 for F_1 ; 100 for F_2 ; 10 -15 for BC_1 and BC_2 generations. Selfed seeds were analyzed for erucic, oleic and linoleic acid by gas liquid chromatograph (NUCON -

[1] Indian Council of Agricultural Research, Krishi Bhawan, New Delhi-110 001.

5765) through the separation of methyl esters on diethylene glycol succinate (DEGS) column as described earlier (Chauhan *et al.*, 2002a).

Means and variances were calculated for each generation separately and used for statistical analysis. Adequacy of additive-dominance model was tested using scales given by Hayman and Mather (1955). Gene effects were estimated following Hayman (1958) using six-parameter model. The significance of gene effects was tested by calculating variances, standard errors and 't' values separately for each effect. Paired 't' test was used to test significance of difference between means of F_1 and its reciprocal. Broad-sense heritability was computed using methods of Burton (1951;1952) and Mahmud and Kramer (1951). Narrow-sense heritability (h^2(ns)) was calculated following the method of Warner (1952). Genetic advance at 5% selection intensity was computed following Allard (1960). Minimum number of effective factor pairs was calculated by following Castle and Wright (1921); Weber (1950) and Burton (1951).

Results and discussion

Analysis of variance and generation means: Analysis of variance revealed highly significant differences among the various generations of the cross TERI (OE) M 21 x RH 30 for erucic, oleic and linoleic acid content. The strain TERI (OE) M 21 had significantly lower erucic acid (1.6%) but significantly higher oleic (38.8%) and linoleic acid (42.5%) content than RH 30 (Table 1). The F_1 mean for erucic, oleic and linoleic acid was close to the mid-parent value. The results revealed the partial dominance of genes governing high erucic, oleic and linoleic acid content. Non-significant difference between F_1 (low x high) and reciprocal (high x low) means for oleic and linoleic acid suggested that maternal effects were not important in the genetics of these fatty acids. However, the mean erucic acid differed significantly between F_1 and its reciprocal (Table 1) indicating the cytoplasmic influence on the expression of erucic acid in this cross. Mean of F_2 generation for all the three fatty acid was similar to the F_1 mean. But both were significantly different from BC_1 and BC_2 means for erucic acid. Mean oleic and linoleic acid in the F_2 generation was close to the BC_2, i.e. recurring parent with low values for both fatty acids. Nevertheless, the BC_1 and BC_2 generation means for erucic, oleic and linoleic acid were clearly skewed towards the recurrent parent indicating that genes controlling these fatty acid had additive effects.

Scaling tests and gene effects: A simple additive -dominance model was not adequate to explain the total genetic variability in different generations for erucic, oleic and linoleic acid in this cross. The scaling test C and D was significant for erucic and oleic acid, respectively whereas B, C and D were significant for linoleic acid. The significance of these tests provides the evidence for presence of non-allelic interactions in controlling the expression of these fatty acids (Table 2) and thus warranted the use of 6-parameter model. Fixable additive [d] and additive x additive [l] types of gene effects were important in the genetic architecture of erucic and oleic acid. The study revealed that it should be possible to develop pure lines with desirable levels of these fatty acids. Similar findings were also reported by Kirk and Hurlstone (1983) and Tiwari' (1995). However, both fixable, [d and l] and non-fixable, dominance [h] and dominance x dominance [l] gene effects with the prevalence of non -additive, duplicate type of gene action (opposite signs of [h] and [l]) controlled the inheritance of linoleic acid. The result of the present investigations corroborated previous findings (Woods *et al.*, 1999; Potts and Males, 1999;Chauhan *et al.*, 2002a,b).

Heritability and effective factor pairs: The heritability estimates in the broad-sense computed by three different methods, varied from 0.91-0.96, 0.86-0.91 and 0.67-0.85 for erucic, oleic and linoleic acid, respectively (Table 3). Narrow-sense heritability that is based on additive genetic variance (fixable component of genetic variance) was also high for erucic and oleic acid but the value was moderate for linoleic acid. The moderates to high heritability estimates were also associated with similar magnitude of genetic advance. The results suggested that simple selection in early segregating generations like F_2 would be quite useful for desirable level of erucic/oleic acid. But selection for linoloeic acid content should be deferred to advanced generation where dominant effects are considerably reduced and preferably based on progeny performance.

The minimum number of effective factor pairs was 2.6 (Castle and Wright, 1921), 2.5 (Weber, 1950) and 0.3 (Burton, 1951) with a mean value of 1.8 for erucic acid. For oleic acid, the minimum number of effective factor pairs was 1.9 (Castle and Wright, 1921), 2.0 (Weber, 1950) and 0.9 (Burton, 1951) with a mean value of 1.6. For linoleic acid content, the number of effective factor pairs was 5.8 (Castle and Wright, 1921), 6.5 (Weber, 1950) and 2.1 (Burton, 1951) and the mean was 4.8. The present investigation revealed that TERI (OE) M 21 and RH 30 differed by at least 2 pairs of major genes each for erucic and oleic acid and 5 genes for linoleic acid. In earlier studies (Tiwari, 1995; Potts and Males, 1999) two genes with additive effects were reported to control erucic acid. The present studies coupled with our earlier reports suggested that linoleic acid is controlled by 2-5 genes. However, Woods *et al.*, (1999) and Potts and Males (1999) reported single major gene for this fatty acid.

Table 1 Mean performance of segregating and non-segregating populations for erucic, oleic and linoleic acid (%) in the cross TERI (OE) M 21 x RH 30 of Indian mustard

Population	Erucic acid		Oleic acid		Linoleic acid	
	Range	Mean ± SEm	Range	Mean ± SEm	Range	Mean ± SEm
P_1	0.0-6.1	1.6^{f} ± 0.7	33.6-43.4	38.8^{a} ± 1.2	36.4-47.4	42.5^{a} ± 1.2
P_2	47.6-55.7	50.5^{a} ± 0.6	9.6-17.1	12.1^{e} ± 0.5	15.5-17.7	16.6^{e} ± 0.2
F_1	24.3-31.9	27.6^{c} ± 1.2	19.4-25.7	22.8^{c} ± 0.8	24.3-31.3	$27.1^{c,d}$ ± 0.7
F_1 (Reciprocal)	16.3-28.1	23.4^{d} ±1.6	16.0-27.9	24.1^{c} ± 1.1	25.2-36.0	30.4^{c} ± 1.3
F_2	0.0-50.1	28.2^{c} ± 1.2	10.5-49.6	$21.4^{c,d}$ ± 0.8	15.0-35.8	24.2^{d} ± 0.5
BC_1	0.0-32.1	13.3^{e} ± 2.2	17.0-45.4	28.9^{b} ± 1.7	22.8-48.5	34.5^{b} ± 1.3
BC_2	22.1-49.8	35.7^{b} ± 1.8	12.5-29.4	18.4^{d} ± 1.1	18.7-33.3	24.3^{d} ± 0.9

* In a column means followed by different letters are different from each other.

Table 2 Scaling test and estimates of gene effects for erucic, oleic and linoleic acid content in the cross TERI (OE) M 21 x RH 30 of Indian mustard

Parameter	*Erucic acid*	Oleic acid	Linoleic acid
A	-2.6 ± 4.6	-3.9 ± 3.7	-0.6 ± 2.9
B	-6.7 ± 3.8	1.8 ± 2.5	4.8** ± 1.9
C	5.6 ± 5.3	-11.0** ± 3.7	-16.6** ± 2.6
D	7.4* ± 3.6	-4.4 ± 2.6	-10.4** ± 1.8
[m]	28.3** ± 1.2	21.4** ± 0.8	24.2** ± 0.5
[d]	-22.4** ± 2.8	1.5 ± 2.0	10.2** ± 1.5
[h]	-13.3 ± 7.5	6.2 ± 5.2	18.3** ± 3.7
[i]	-14.9* ± 7.3	8.9* ± 4.1	20.8** ± 3.6
[j]	2.1 ± 2.9	-2.9 ± 2.2	-2.7 ± 1.6
[l]	24.1 ± 12.5	-6.8 ± 9.0	-24.9** ± 6.7

*,** : significant at 5 and 1 % probability level, respectively.

Table 3 Estimates of heritability and genetic advance (as % of mean) under selection for erucic, oleic and linoleic acid content in the cross TERI (OE) M 21 x RH 30 of Indian mustard

Method	Erucic acid		*Oleic acid*		Linoleic acid	
	Heritability	Genetic advance	Heritability	Genetic advance	Heritability	Genetic advance
Broad-sense						
Burton (1951)	0.91	75.1	0.91	66.3	0.76	28.4
Mahmud & Kramer (1951)	0.96	79.2	0.87	73.1	0.85	31.6
Burton (1952)	0.94	77.8	0.86	62.6	0.67	25.1
Mean	0.94	77.4	0.88	64.0	0.76	28.4
Narrow-sense						
Warner (1952)	0.85	70.2	0.63	45.8	0.26	9.9

On the basis of estimates of gene effects, heritability and number of effective factor pairs, it is suggested that for the improvement of erucic and oleic acid content in Indian mustard, simple pedigree selection would be effective in early segregating generations. Biparental mating and recurrent selection coupled with selection in advanced generation should be followed for developing genotypes with desired level of linoleic acid.

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J. Oilseeds Res., **23**(2) : 281-284 (2006)

Redox responses of seedlings of groundnut genotypes to water deficit stress under amelioration by trehalose and L-ascorbic acid

Virendra Kumar, A. Joshi[1], G. Rajamani, A. Sharma and P.N. Mathur

Dept. of Molecular Biology and Biotechnology, *Rajasthan College of Agriculture, MPAUT*, Udaipur-313 001, Rajasthan

(Received: December, 2005; Revised: April, 2006; Accepted: June, 2006)

Abstract

Amelioration with *trehalose or ascorbic acid* enhanced superoxide as well as hydrogen peroxide accumulation and consequent lipid peroxidation in *both cultivars* of groundnut, i.e., JL-24 and TG-37A. The activities of superoxide dismutase and ascorbate peroxidase were enhanced as well. The accumulation of osmoprotective soluble sugars was also enhanced by these ameliorants. The magnitude of these responses was higher in trehalose ameliorated tissue compared to ascorbate treated tissue. These responses were relatively more pronounced in TG-37A (relatively tolerant) genotype.

Key words: Groundnut, L.-ascorbic acid, lipid peroxidation, *osmoregulation*, PEG-6000, reactive oxygen species, trehalose, water-deficit stress

Introduction

Groundnut, an important cash crop amongst oilseeds, is *cultivated in different soil* moisture regimes. Its productivity is often affected by water-deficit situation. Acclimation to abiotic stresses in plants is found to occur *by triggering* of a cascade of biochemical events (Pastori and Foyer, 2002). Various interacting signals namely 'redox' signals are the key regulators of plant metabolism. In response to stress, the flux of hydrogen peroxide generation is increased. This flux is regulated by major antioxidants such as ascorbate and glutathione (Noctor and Foyer, 1998).

The ascorbate is reported to have significant roles in *scavenging or detoxification* of reactive oxygen species thus protecting plants against oxidative damage during aerobic metabolism, photosynthesis and a range of pollutants. (Dietz and Scheibe, 2004). The non-reducing sugar disaccharide trehalose, an osmoprotectant, is found to possess protective role i.e. stabilization of biological structures as well as to scavenge the reactive oxygen (Garg *et al.*, 2002). In the present paper, the flux of superoxide anion and hydrogen peroxide generation, malondialdehyde and their scavengers like ascorbic acid, superoxide dismutase and ascorbate peroxidase along with sugars under influence of ameliorants trehalose and L-ascorbic acid during water deficit stress induced by PEG-6000 in seedlings of two groundnut genotypes *viz.*, JL-24 and TG-37A, are reported.

Material and methods

Seeds of two genotypes *viz.*, JL-24 and TG-37A having uniform weights (70 mg ± 15 mg) were surface sterilized using 0.1% mercuric chloride solution followed by five rinses in sterile distilled water and then soaked in two concentrations of polyethylene glycol - 6000 (PEG-6000) *viz.*, -3.0 bars and -6.0 bars of external water potential for 06, 12, 18 and 24 hr so as to obtain optimal water uptake by the seeds under influence of the *chemical*. The PEG-soaking was done in Petri plates layered with one circle of ordinary filter paper. Percent imbibition for all the time periods was *calculated using the formula* :

$$\text{Imbibition (\%)} = \frac{\text{Fresh weight (initial) - Oven dry weight}}{\text{Imbibed weights (6, 12, 18, 24 hr) - Oven dry weight}} \times 100$$

After induction of PEG-stress, the seeds were treated with ameliorants *viz.*, *25 mM each of trehalose* and *L*-ascorbic acid, 20 hr after removal from the two stress levels of PEG-6000 along with respective controls. The *amelioration was continued* for 100 hr in the respective solutions of trehalose and ascorbate until embryonic axes of the seeds were found suitable for sampling to conduct biochemical estimations.

The contents of reactive oxygen species (ROS), *viz.*, superoxide anion and hydrogen peroxide were estimated following procedures given by Dai *et al.* (1997). Lipid peroxidation was measured by estimating content of malondialdehyde as per Heath and Packer (1968).

Activities of superoxide dismutase (SOD) was estimated by the method of Madesh and Subrahmanian (1998) and that of ascorbate-peroxidase (APX), as per Meneguzzo *et al.* (1998). For both enzymes, water soluble protein content from *crude extracts were determined by the* procedure given by Lowry *et al.* (1951).

[1] Associate Professor, Department of Molecular Biology and Biotechnology, RCA, Udaipur.

Levels of endogenous ascorbic acid in the tissues were determined using the dye method of Freed (1966). Contents of (total, reducing and non-reducing) sugars was determined by the method of Hedge and Hofreiter (1962).

Results and discussion

The groundnut genotype TG-37A was more tolerant to PEG-6000 induced water stress compared to JL-24 since its seeds could imbibe more water than control at -3.0 bars osmotic pressure even after 24 hr and its water intake capacity was better than JL-24 against -6.0 bars osmotic pressure and in normal water (Table 1). A stress period of 18 hr was however, chosen since water uptake by both genotypes in control was nearly same and the differential water uptake by the two genotypes was more pronounced.

The accumulation of superoxide anion was significantly higher in -3.0 bars than -6.0 bars osmoticum in both genotypes, in the absence of ameliorants (Table 2), which could be due to higher activity of superoxide dismutase (SOD) enzyme in the latter (Table 4).

Trehalose as well as ascorbic acid amelioration enhanced superoxide anion and hydrogen peroxide accumulation under both levels of water stress, the magnitude of enhancement was much higher with trehalose (Table 2). Since the activities of ROS-scavenging enzymes superoxide dismutase and ascorbate peroxidase were concomitantly enhanced, it may be inferred that amelioration induced higher rate of generation of ROS. Non-enzymatic reduction of ROS by ascorbate may also be responsible for lower accumulation with ascorbic acid amelioration (Table 3).

Increase in hydrogen peroxide production (as a result of oxidative burst) has been noticed by action of plasma-membrane associated NADPH-dependent superoxide synthase together with apoplastic SOD during hypersensitive response (Varnova *et al.*, 2002). There are several lines of evidence suggesting strongly that hydrogen peroxide initiates a signal transduction process for acquisition of tolerance to abiotic and biotic stresses (Bhattacharjee, 2005). Abscisic acid (ABA) is implicated in a number of abiotic stress responses associated with dehydration such as drought, cold, salinity and heat shock (Grill and Zeigler, 1998). It was demonstrated that ABA induces generation of hydrogen peroxide in stomatal guard cells and hydrogen peroxide activated calcium influx as well as stomatal closure. Ethylene, another stress hormone is also found to interact with ROS in their signaling network (Bhattacharjee, 2005). The ameliorative action of treahalose and ascorbic acid against water stress may therefore, be due to the induction of greater accumulation of hydrogen peroxide.

Degradation of membrane lipids, resulting in free fatty acids, initiates oxidative deterioration by providing a substrate for enzyme lipoxygenase, causing membrane lipid peroxidation. Since lipid peroxidation is known to produce alkoxy, peroxy radicals as well as singlet oxygen, these reactions in the membrane are a major source of ROS in plant cells. Alternatively over production of ROS has also been implicated in membrane lipid peroxidation.

In the present study, lipid peroxidation (measured as malondialdehyde accumulation, (Table 3) was higher in stressed, non-ameliorated JL-24 embryonic axial tissue compared to similar TG-37A tissue. Amelioration with trehalose as well as ascorbic acid significantly enhanced lipid peroxidation which could have been a source of ROS accumulation leading to the triggering of stress acclimation responses.

Trehalose and ascorbic acid amelioration also significantly increased accumulation of soluble sugars which are known to function as osmoprotectants under water stress by maintaining structural and functional integrity of macromolecules (Hoekstra and Buitink, 2001). Higher accumulation soluble sugars in trehalose ameliorated stressed TG-37A (more tolerant) genotype strengthens this contention (Table 5). Water stress amelioration action of trehalose and ascorbic acid may therefore be mediated by a combination of the enhancement of ROS signaling of stress acclamatory responses as well as the accumulation of osmoprotectants like soluble sugars. These responses were more pronounced in the relatively tolerant TG-37A genotype.

Table 1 Effect of PEG-6000 induced water stress on water uptake capacity (%) of two groundnut genotype seeds (0-24 hr imbibition period)

Stress level (EWP bars)	6 hr			12 hr			18 hr			24 hr		
Genotype	Control	-3.0	-0.6	Control	-3.0	-6.0	Control	-3.0	-6.0	Control	-3.0	-6.0
JL-24	40.6	44.8	30.7	55.7	46.1	37.4	57.3	54.3	42.2	57.3	55.4	45.9
TG-37A	47.1	50.5	41.0	51.1	59.3	48.0	56.1	62.6	51.7	59.6	63.3	56.7
SEm±		0.77			0.92			1.07			1.00	
CD (P=0.05)		2.28			2.74			3.18			2.99	
CV (%)		2.72			2.79			2.97			2.68	

Table 2 **Effect of trehalose and L-ascorbic acid amelioration on contents of the superoxide anion (μ moles/100 mg), hydrogen peroxide (millimoles/100 mg), in 18 hr PEG-stressed germinating embryonic tissue (120 hr old) of two groundnut genotypes**

Genotype	Stress level (EWP bars)	Control		Trehalose*		L-Ascorbic acid*		Ratio			
								Trehalose		Ascorbic acid	
		Superoxide anion	Hydrogen peroxide	Superoxide anion	Hydrogen peroxide	Superoxide anion	Hydrogen peroxide	Superoxide anion	Hydrogen peroxide	Superoxide anion	Hydrogen peroxide
JL-24	-3.0	0.012	0.26	0.034	0.45	0.024	0.29	2.83	1.73	2.00	1.11
	-6.0	0.010	0.28	0.045	0.48	0.023	0.31	4.50	1.71	2.30	1.10
TG-37A	-3.0	0.039	0.30	0.094	0.46	0.050	0.43	2.41	1.53	1.28	1.43
	-6.0	0.020	0.35	0.086	0.58	0.047	0.43	4.30	1.65	2.35	1.22
	Superoxide anion				**Hydrogen peroxide**						
SEm±	0.001			SEm±	0.004						
CD (P=0.05)	0.002			CD (P=0.05)	0.012						
CV (%)	2.88			CV (%)	2.26						

1 = Ratio = Values of ascorbic acid/trehalose ameliorated/respective control.
2 = EWP = External water potential; * = 25 mM concentrations

Table 3 **Effect of trehalose and L-ascorbic acid amelioration on contents of the malondialdehyde (millimoles/100 mg), endogenous ascorbic acid (mg %) in 18 hr PEG-stressed germinating embryonic tissue (120 hr old) of two groundnut genotypes**

Genotype	Stress level (EWP bars)	Control		Trehalose*		L-Ascorbic acid*		Ratio			
								Trehalose		Ascorbic acid	
		Malondi-aldehyde	Ascorbic acid	Malondi-aldehyde	Ascorbic acid	Malondi-aldehyde	Ascorbic acid	Malondi-aldehyde	Ascorbic acid	Malondi-aldehyde	Ascorbic acid
JL-24	-3.0	13.20	0.11	25.67	0.05	34.12	0.11	1.94	0.45	2.58	1.00
	-6.0	17.05	0.06	30.21	0.04	65.09	0.11	1.77	0.66	3.81	1.83
TG-37A	-3.0	6.23	0.08	22.59	0.06	25.67	0.11	3.62	0.75	4.12	1.37
	-6.0	7.84	0.07	39.56	0.06	41.18	0.10	5.04	0.85	5.25	1.42
	Malondialdehyde				**Ascorbic acid**						
SEm±	0.40			SEm±	0.001						
CD (P=0.05)	1.15			CD (P=0.05)	0.003						
CV (%)	2.94			CV (%)	2.84						

1 = Ratio = Values of ascorbic acid/trehalose ameliorated/respective control.
2 = EWP = External water potential; * = 25 mM concentrations

Table 4 **Effect of trehalose and L-ascorbic acid amelioration on activities of ROS-scavenging enzymes, superoxide dismutase (U/min/mg protein) and ascorbate peroxidase (U/min/mg protein) in 18-hr PEG-stressed germinating embryonic tissue (120 hr old) of two groundnut genotypes**

Genotype	Stress level (EWP bars)	Control		Trehalose*		L-Ascorbic acid*		Ratio			
								Trehalose		Ascorbic acid	
		Superoxide anion	Hydrogen peroxide	Superoxide anion	Hydrogen peroxide	Superoxide anion	Hydrogen peroxide	Superoxide anion	Hydrogen peroxide	Superoxide anion	Hydrogen peroxide
JL-24	-3.0	0.20	2.34	0.37	2.61	0.24	2.73	1.85	1.11	1.20	1.16
	-6.0	0.21	2.58	0.39	2.87	0.28	2.91	1.85	1.11	1.33	1.12
TG-37A	-3.0	0.19	2.46	0.33	2.80	0.31	3.05	1.73	1.13	1.63	1.23
	-6.0	0.21	2.29	0.40	2.51	0.34	2.94	1.90	1.09	1.66	1.28
	Malondialdehyde				**Ascorbic acid**						
SEm±	0.004			SEm±	0.03						
CD (P=0.05)	0.01			CD (P=0.05)	0.09						
CV (%)	2.98			CV (%)	2.35						

1 = Ratio = Values of ascorbic acid/trehalose ameliorated/respective control.
2 = U = *one unit SOD and APX activity was defined as the change in optical density per minute per mg protein*
3 = EWP = External water potential; * = 25 mM concentrations

Table 5 **Effect of trehalose and L-ascorbic acid amelioration on contents of reducing sugars, non-reducing sugars and total soluble sugars in mg/100 mg fresh weight in 18 hr PEG-stressed germinating embryonic tissue (120 hr old) of two groundnut genotypes**

Genotype	Stress level (EWP bars)	Control			Trehalose*			L-Ascorbic acid*			Ratio					
											Trehalose			L-Ascorbic acid		
		Reducing sugars	Non-reducing sugars	Total soluble sugars	Reducing sugars	Non-reducing sugars	Total sugars	Reducing sugars	Non-reducing sugars	Total soluble sugars	Reducing sugars	Non-reducing sugars	Total soluble sugars	Reducing sugars	Non-reducing sugars	Total soluble sugars
JL-24	-3.0	4.13	6.98	11.25	4.62	12.20	16.71	5.00	9.30	14.25	1.11	1.74	1.48	1.21	1.33	1.26
	-6.0	4.62	8.10	12.60	5.00	17.60	22.53	5.62	10.60	16.23	1.08	2.17	1.78	1.22	1.30	1.28
TG-37A	-3.0	4.00	5.42	10.38	4.63	10.40	21.38	9.75	7.30	14.25	1.15	1.91	2.05	2.43	1.34	1.37
	-6.0	4.38	6.80	11.93	7.13	12.40	22.16	11.13	9.20	13.68	1.62	1.82	1.85	2.54	1.35	1.14

	Reducing sugars		Non-reducing sugars		Total soluble sugars	
SEm±	0.08	SEm±	0.13	SEm±	0.19
CD (P=0.0r)	0.23	CD (P=0.0r)	0.39	CD (P=0.0r)	0.55
CV (%)	2.81	CV (%)	2.86	CV (%)	2.48

1 *Ratio = Values of ascorbic acid/trehalose ameliorated/respective control*
2 EWP = External water potential; * = 25 mM concentration

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J. Oilseeds Res., **23(2) : 285-287 (2006)**

Short communication

Cytogenetic study of *Helianthus tuberosus* and its F_1 hybrid with cultivated sunflower, *Helianthus annuus* L.

C.R. Kesavaraman, N. Sreedhar and A.J. Prabhakaran[1]

Department of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad-500 030, AP

(Received: April, 2005; Revised: September, 2005; Accepted: December, 2005)

The genus *Helianthus* (Asteraceae) contains 49 species distributed into 4 sections according to the systematics of Schilling and Heiser (1981). The perennial species were distributed taxonomically into different sections and series and possessed different ploidy levels (diploid, tetraploid and hexaploid). Hybridization and study of meiosis and pollen viability in F_1 hybrids showed that belonging to different sections and series is a higher obstacle for interspecific crossing than different levels of ploidy (Georgieva-Todorova, 1990).

Among the several hexaploid species, *Helianthus tuberosus* received great attention since it exhibited high degree of resistance to leaf spot caused by *A. helianthi* besides its cross compatibility with cultivated sunflower (Sujatha *et al.*, 1997). In the present investigation an attempt was made to determine the extent of genetic similarity between *H. tuberosus* and cultivated sunflower i.e., phylogenetic relationship between these two species by studying meiosis and pollen viability in each species and F_1 interspecific hybrids.

The study included three populations (Tub 03, Tub 04 and Tub 07) and their F_1 interspecific hybrids and cultivated sunflower maintained at the Crop Improvement Section, Directorate of Oilseeds Research, Rajendranagar, Hyderabad. Meiosis was analyzed in the populations of *H. tuberosus* and interspecific hybrids by acetocarmine method. Anthers were fixed in Carnoy's III solution (6:3:1 - Ethyl alcohol, chloroform and glacial acetic acid). Meiocytes were also observed at diakinesis (chromosome pairing), metaphase I (fast chromosomes), anaphase I (chromosome disjunction laggards) and telophase II (micronuclei). Pollen viability was determined by the staining method (Alexander, 1969). Observations were made on temporary squash preparations. Meiotic irregularities were expressed as percentage meiocytes with deviations in relation to the total number of PMC studies.

Meiotic studies on parental species and interspecific hybrids: Meiosis in the parental species, *Helianthus tuberosus* and *H. annuus* was normal as expected (Table 1). Only normal bivalents were observed in the parents and the number of bivalents per meiocytes was 51 and 17 in *H. tuberosus* and *H. annuus*, respectively.

H. tuberosus recorded more ring bivalents (23.65) followed by rod bivalents (17.30) and open ring bivalents (9.95), whereas the *H. annuus* recorded 9.4 ring bivalents followed by 5.3 open ring bivalents and 2.3 rod bivalents. No chromosome abnormalities were observed in anaphase I separation in *H. annuus* but interestingly, few meiocytes in *H. tuberosus* showed some abnormalities like fast chromosomes (4.0%) and chromosome bridges (3.0%) but no micronuclei were observed.

In contrast to parental species, meiosis in interspecific hybrid was highly irregular with presence of univalents, bivalents, quadrivalents and multivalents. The average number of bivalents per meiocyte was 26.92 and the percentage of meiocytes with bivalents was 79.18. More number of ring bivalents were observed than other forms of bivalents and it was higher (14.82) than the number of rod bivalents (7.18). In addition to the bivalents, a significant percentage of 17.822 meiocytes were found to show multivalents at diakinesis stage (trivalents, quadrivalents, hexavalents and octavalents) with varied frequencies. Among the multivalent configurations, quadrivalents occurred more frequently (1-4) in 15.88% of the cells, 2.74% of cells showed univalents ranging from 1-6. The mean chromosome association was 1.86 I + 26.92 II + 0.44 III + 2.70 IV + 0.02 VI + 0.01 VIII.

High percentage (36) of meiocytes showed fast chromosomes with a range of 1-4 in metaphase I. In anaphase I, lagging chromosomes (1-3) and chromosome bridges (1-5) were registered in 21% and 39% of the cells observed, respectively. However, only 9 per cent of meiocytes showed micronuclei (1-2) at telophase II.

In the interspecific hybrid, the pollen fertility ranged from 35.27% to 74.73% with an average of 52.05% as against 95.2% and 98.6% in *H. tuberosus* and *H. annuus*, respectively.

[1] Senior Scientist, Regional Research Station on Wheat, Indian Agril. Research Institute, Wellington, Tamil Nadu.

Characteristics of meiotic chromosome pairing: Interspecific hybrids between *H. tuberosus* and cultivated sunflower were also reported by Georgieva-Todorova (1990) and Atlagic *et al.* (1993). The interspecific hybrid was intermediate between the parents and mostly dominated by characters of the wild parent *viz.*, profuse branching, leaf shape, size, stem pigmentation, head size, head diameter, late flowering. The hybrid flowered during April-May and was perennial. It recorded very low seed set and pollen fertility ranged from 35.27% to 74.73%.

In contrast to *H. tuberosus* and *H. annuus,* the interspecific hybrid showed high percentage of meiotic abnormalities like fast chromosomes (1-5), lagging chromosomes (1-3) and chromosome bridges (1-5) in 36%, 21% and 39% of the cells observed, respectively, during metaphase I and anaphase I. Similar results have been reported by Atlagic *et al.* (1993). The reduced pollen fertility of the interspecific hybrid (52.05%) in the present study could be attributed to the high incidence of meiotic abnormalities like chromosome bridges and fragments and laggards. Atlagic *et al.* (1993) observed existence of negative correlation between pollen fertility and chromosomal abnormalities in the F_1 hybrids of *H. tuberosus* with cultivated sunflower.

Among the various chromosome associations, bivalents were observed in 79.18% of the cells with an average of 26.92 bivalents per meiocyte. Among the several bivalent configurations, ring bivalents (14.82) out numbered rod (7.18) and open ring (4.92) bivalents. These results corroborated the findings of Cedeno *et al.* (1985) that the ring bivalents are most probably formed by autosyndesis and rod bivalents are heteromorphic (formed by conjugation between homoeologous chromosomes).

Table 1 Frequency of different meiotic configurations in *H. annuus, H. tuberosus* and their interspecific hybrid

Stage	Characteristics	*H. tuberosus* (2n=102)	Interspecific hybrid (2n=68)	*H. annuus* (2n=34)
Diakinesis	Bivalents / Meiocyte	51.0	26.92	17.0
	Ring bivalents/meiocyte	23.65	14.82	9.4
	Rod bivalents/meiocyte	17.30	7.18	2.3
	Open ring bivalents/meiocyte	9.95	4.92	5.3
	Univalents/meiocyte	0.0	0-6	0.0
	Trivalents/meiocyte	0.0	0-2	0.0
	Quadrivalents/meiocyte	0.0	1-4	0.0
	% of meiocyte with univalents	0.0	2.74	0.0
	Bivalents	100.0	79.18	100.0
	Trivalents	0.0	1.94	0.0
	Quadrivalents	0.0	15.88	0.0
	Hexavalents	0.0	0.001	0.0
	Octavalents	0.0	0.001	0.0
	Multivalents	0.0	17.82	0.0
	Mean chromosome association	51 II	1.86 I + 26.92 II + 0.44 III + 2.70 IV + 0.02 VI + 0.01 VIII	17 II
Metaphase I	% of cells with fast chromosomes	4.0	36.0	0.0
Anaphase I	% of cells with lagging chromosomes	3.0	21.0	0.0
	% of cells with chromosome bridges	0.0	39.0	0.0
Telephase II	% of cells with micronuclei	0.0	9.0	0.0
	Pollen fertility (%)	95.2	52.05	98.6

About 17.82% of the PMCs showed multivalents in which quadrivalents (2-4) accounted more frequently in 15.88% of the PMCs followed by trivalents, hexavalents and octavalents. A significant number of meiocytes (2.74%) showed univalents ranging from 2 to 6. Chandler *et al.* (1986) considered incomplete pairing of homologous chromosomes as the cause of univalents while, Narkhede *et al.* (1986) considered dissociation of quadrivalents as the cause for the formation of trivalents and univalents.

Manjula *et al.* (1999) reported that the quadrivalents were responsible for the exchange of unequal chromosome segments between the non-homologous chromosomes during meiosis (reciprocal chromosomal translocation).

The occurrence of high number of bivalents (26.92 out of 34 maximum possible) also indicated that one of the three genomes of *H. tuberosus* shared similarity with *H. annuus* provided *H. annuus* was an auto tetraploid. Kostoff (1939) assigned a genomic formula for *H. tuberosus* as At_1 At_2 Ba and for *H. annuus* as Ba. The F_1 hybrid was assigned At_1 Ba/At_2 Ba. This amphiploid hypothesis was supported by the present findings that *H. tuberosus* and *H. annuus* shared one genome (Ba) in common and the other genome (At_1 and At_2) of *H. tuberosus* differ by structural rearrangements, but sharing limited similarity. As a consequence, they formed mostly bivalents and univalents and multivalents to a limited extent. Hence, the present study supported both autoploidy and amphidiploid origin of *H. tuberosus*.

It is concluded that crossing of hexaploid *H. tuberosus* with cultivated sunflower (*H. annuus*) is possible for transfer of desirable genes but, with some difficulty.

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J. Oilseeds Res., 23(2) : 288-291 (2006)

Short communication

Combining ability and gene action in sunflower, *Helianthus annuus* L.

S.J. Vishwanath[1] and I. Shanker Goud

Regional Agricultural Research Station, University of Agricultural Sciences, Raichur-584 101, Karnataka

(Received: July, 2005; Revised: March, 2006; Accepted: June, 2006)

Sunflower (*Helianthus annuus* L.) has become an important contributing crop to the edible oil industry due to its promising agronomic and quality characters. There has been a dramatic improvement in seed and oil yield after the exploitation of heterosis in this crop. However, the productivity of Sunflower crop in India (549 kg/ha) is much lower than the world average (1247 kg/ha) (Anonymous, 2001) and hence the improvement of productivity is currently an important breeding objective for this crop.

The heterotic performance of a hybrid depended upon the combining ability of the parents and thus testing of inbred lines for their general combining ability (*gca*) is a crucial step in hybrid development. The line x tester analysis (Kempthrone, 1957) is one of the simplest and efficient method of evaluating large number of inbreds for their combining ability and per se performance. The *gca* and *sca* help in interpreting the genetic basis and nature of gene action controlling different traits.

The experimental material comprised of three cytoplasmic genic male sterile lines. CMS-4546A, CMS-10A, CMS-103A and five restorer lines viz. R-3Br, R-64NB, R-16NB, R-3NB and R-12NB which are mated in a line x tester fashion to obtain 15 single cross hybrids. These crosses along with their eight parents were grown in a randomised block design with three replication at Regional Agril. Research Station, Raichur campus located in North Eastern dry zone of the Karnataka (latitude 16° 12' N, longitude 77° 21'E) India.

The crossing and evaluation was done during 2001-02. Each entry was grown in rows of 3m length with a spacing of 60 x 30 cm^2. All the recommended package of practice was followed and observations were recorded on days to 50% flowering, plant height, plant yield, oil content and protein content. The oil content was analysed by using Nuclear Magnetic Resonance Spectro photometer.

The analysis of variance indicated that the parents exhibited significant differences for all the characters studied revealing the existence of genetic diversity in parental material and justifying their selection for combining ability analysis. Both lines and testers exhibited significant difference among themselves for most of the characters. Further crosses were also found to be significantly different from each other for all the characters (Table 1). The diverse nature of testers and significant interaction between lines and testers contributed towards variations considerably. It also suggests significant contribution of *sca* effects towards the variations among crosses. The ratio of *gca/sca* variances for all the characters expect for plant height and kernel protein content, indicating predominance of non-additive gene action for expression of major yield components and additive gene action for plant height and protein content. These results are comparable with earlier reports by Lande *et al.* (1997), Kumar *et al.* (1998), Shekar *et al.* (1998), and Nirmala *et al.* (2000). It is however, desirable to exploit both additive and non-additive genetic variances in sunflower breeding programme to develop populations and hybrids.

The estimates of *gca* and sca effects of eight parents and 15 hybrids, respectively for eight characters are presented in Table 2. It is evident that no single line or testers was a common good general combiners for all the characters studied. The line CMS10A and testers R-3 NB exhibition significant *gca* effects for days to 50% flowering and days to maturity in the desirable direction. While the line CMS-103A and tester R-64NB exhibited high significant *gca* effects for head diameter, plant yield and oil content. In general, the lines and testers which were good combiners for earliness were poor combiners for yield and oil content. Over all, the line CMS-103A and tester R-64 NB were the best general combiners for major yield attributing characters. The tester R-3 NB exhibited highly significant *gca* effect for kernel protein content and earliness while, it was poor combiner for plant yield and oil content indicating that improvement in protein content and oil content can not go hand in hand. The R-3NB believed to posses unfavorable alleles for oil content and plant yield. Significant and positive *gca* effects for oil yield and other yield attributes has been reported by earlier works (Kadakol *et al.*, 1984; Gangappa *et al.*, 1997; Shekar *et al.*, 1998).

[1] M.Sc. (Ag.) Student.

The results on specific combining ability of some promising crosses (Table 3) revealed, that, the cross CMS-103A x R-64NB had the high significant *sca* effect to days to 50% flowering and plant yield. Though both the parents in this cross had positive *gca* effect for days to 50% flowering, the negative *sca* effect in the cross may be attributed to the favorable epistatic interaction of genes from the two parents.

Table 1 Mean *per se* performance of parents and hybrids for eight different characters in sunflower

Parents of Hybrids	Days to 50 percent flowering	Plant height (cm)	Head diameter (cm)	Days to maturity	Hundred seed weight (g)	Plant yield (g)	Oil content (%)	Kernel protein content (%)
CMS-4546A	56.3**	87.0**	15.3	86.7**	5.2	42.9	34.9	23.2
CMS-10A	57.7*	145.0**	16.6	88.3**	4.3	36.9	36.2**	23.4
CMS-103A	64.0	140.3**	18.8*	94.7	5.6	52.0**	37.6**	25.3
R-3 Br	57.3**	126.7**	13.8	88.7**	4.3	23.3	36.9**	22.1
R-64NB	68.3	135.7**	17.6	98.7	5.6	48.1**	36.8**	27.6
R-12NB	67.0	135.0**	16.3	98.0	5.8	42.3	36.7**	24.4
R-3NB	66.3	130.7**	14.7	97.3	4.9	38.3	33.7	27.4
R-16NB	59.0	139.3**	15.5	91.0*	5.7	26.6	37.1**	25.3
CMS-4546 A X R-3Br	58.0*	126.3**	15.1	89.7**	5.2	52.1**	35.5*	25.0
CMS-4546 A X R-64NB	66.7	140.0**	20.3**	97.3	6.4*	46.5*	38.4**	26.6
CMS-4546 A X R-12NB	59.7	135.3**	15.9	90.7**	5.6	51.2**	34.2	25.6
CMS-4546 A X R-3NB	57.7*	132.7**	15.3	89.3**	5.4	58.5**	35.2	27.6
CMS-4546 A X R-16NB	58.3	145.3**	15.7	90.0**	5.3	52.6**	36.7**	26.6
CMS-10 A X R-3Br	57.3**	135.7**	16.1	90.0**	4.9	51.7**	35.8**	25.5
CMS-10 A X R-64NB	59.7	150.7*	16.8	90.7**	5.4	52.0**	35.4*	26.6
CMS-10 A X R-12NB	57.7*	148.7**	15.6	89.7**	5.6	53.7**	36.6**	26.0
CMS-10 A X R -3NB	58.3	139.7**	16.3	91.3*	5.1	48.5**	35.4*	29.2*
CMS-10 A X R-16NB	58.0*	160.3	15.4	90.7**	5.7	48.4**	35.7**	27.4
CMS-103 A X R-3Br	62.3	158.3	16.2	92.7	5.3	61.0**	35.9**	25.6
CMS-103 A X R-64NB	63.3	150.7*	18.8*	94.7	5.9	85.6**	37.5**	26.7
CMS-103 A X R-12NB	61.7	150.3*	16.5	92.3	5.7	76.4**	36.4**	25.6
CMS -103 A X R-3NB	61.0	158.7	15.5	91.7	5.4	52.6**	34.7	30.3**
CMS-103 AXR-16NB	62.3	162.0	15.9	93.3	5.5	61.7**	36.7**	26.2
Checks								
KBSH-1	58.0	158.0	16.6	90.0	5.7	35.3	39.7	26.2
MSFH-17	60.0	156.0	18.0	94.0	5.9	41.9	34.5	28.1
CD (P=0.05)	1.9	4.3	0.8	2.5	0.5	4.4	0.2	1.0
CD (P=0.01)	2.5	5.8	1.0	3.3	0.7	5.9	1.1	1.4

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

Table 2 **Estimates of *gca* effects of lines and testers for eight different characters in sunflower**

Parents	Days to 50% flowering	Plant height (cm)	Head diameter (cm)	Days to maturity	Hundred seed weight (g)	Plant yield (g)	Oil content (%)	Kernel protein content (%)
Lines								
1. CMS-4546 A	-0.07	-10.38**	0.14**	-0.20	0.10*	-4.65**	0.01	-0.41**
2. CMS-10 A	-1.93**	0.69	-0.30**	-1.13**	-0.15**	-5.97**	-0.23**	0.25**
3. CMS-103 A	2.00**	9.69	0.15**	1.33**	0.06	10.63**	0.22**	0.16
Testers								
1. R-3Br	-0.91**	-6.20**	-0.55**	-0.83*	-0.33**	-1.91**	-0.26*	-1.35**
2. R-64NB	3.09**	0.8	2.18	2.62**	0.35**	4.55**	1.11**	-0.05
3. R-12NB	-0.47	-1.53*	-0.34**	-0.17	0.15*	3.57**	-27**	-0.97**
4. R-3NB	-1.13**	-2.64**	-0.62**	-0.83*	0.19	3.64**	-0.94**	2.33**
5. R-16NB	-0.58*	9.58**	-0.67**	-0.27	0.01	-2.57**	0.36**	0.04
GCA (Lines)								
CD (P=0.05)	0.42	0.99	0.10	0.58	0.08	0.87	0.16	0.18
CD (P=0.01)	0.56	1.32	0.13	0.78	0.11	1.16	0.21	0.24
GCA Testers								
CD (P=0.05)	0.58	1.39	0.16	0.83	0.12	1.23	0.24	0.26
CD (P=0.01)	0.78	1.86	0.21	1.10	0.16	1.64	0.32	0.35

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

Table 3 Estimates of sca effects of hybrids for eight different characters in sunflower

Hybrids	Days to 50% Flowering	Plant Height (cm)	Head diameter (cm)	Days to maturity	100 seed weight (g)	Plant yield (g)	Oil content (%)	Kernel protein content (%)
CMS-4546 A x R-3Br	-1.16**	-3.40**	-0.83**	-0.91	-0.03	1.84*	-0.21	0.04
CMS-4546 A x R-64NB	3.51**	3.27**	1.67**	3.31**	0.31**	-10.18**	1.29**	0.37*
CMS-4546 A x R-12 NB	0.07	0.93	-0.22*	-0.02	-0.09	-4.59**	-1.50**	0.29
CMS-4546 A x R-3NB	-1.27**	-0.62	-0.55*	-1.24*	0.05	9.94**	0.12	-1.01**
CMS-4546 A X R-16NB	-1.16**	-0.18	-0.06	-1.13	-0.24**	2.99**	0.31	0.31
CMS-10 A x R-3Br	0.04	-5.13**	0.59**	0.36	-0.07	2.72**	0.31	-0.08
CMS-10 A x R-64NB	-1.62**	2.87**	-1.36**	-2.42**	-0.28**	-3.41**	-1.47**	-0.29
CMS-10 A x R-12NB	-0.07	3.20**	-0.12	-0.09	0.10	-0.75	1.11**	0.03
CMS-10 A x R-3NB	1.27**	-4.69**	0.88**	-1.69**	-0.06	1.30	0.51**	-0.08
CMS-10 A x R-16NB	0.38	3.76**	0.00	0.47	0.31**	0.15	-0.46**	0.42*
CMS-103 A x R-3Br	1.11*	8.53**	0.25*	0.56	0.09	-4.56**	-0.10	0.04
CMS-103 A x R-64NB	-1.89**	-6.13**	-0.32**	-0.89	-0.03	13.59**	0.18	-0.08
CMS-103 A x R-12NB	0.00	-4.13**	0.34**	0.11	0.00	5.34**	0.39*	-0.32
CMS-103 A x R- 3NB	0.00	5.31**	-0.33**	-0.44	0.02	-11.24**	-0.63**	1.09**
CMS-103 A x R- 16NB	0.78	-3.58**	0.06	0.67	-0.08	-3.13**	0.15	-0.73**
CD (P=0.05)	0.85	1.97	0.22	1.17	0.16	1.73	0.34	0.36
CD (P=0.01)	1.13	2.64	0.3	1.56	0.22	2.31	0.46	0.48

The cross CMS 4546A X R-64 NB was the best specific combiner for head diameter, hundred seed weight and oil content, while, CMS-103A X R-3NB as evident by its high *gca* effect. The cross CMS-10A X R-64 NB was the best specific combiner for earliness. Though the *gca* effect of these two parental lines are in opposite direction the significant sca effect may be due to the presence of the dominant alleles for earliness in the CMS-10 A. The crosses which have high *gca* effect and high *per se* performance for the yield components could be utilized in a heterosis breeding programme. Interestingly the testers R-64 NB was involved as common male parent in most of the hybrids exhibiting significant *sca* effect in favorable direction for days to 50% flowering, plant height, head diameter, days to maturity, hundred seed weight, plant yield and oil content It appears to transmit additive genes for earliness and higher seed yield. Similar was the case with CMS-4546A. Therefore, it could be ascertained that these two lines are most versatile in their ability to combine among the parental lines and are promising lines.

The perusal of the *sca* effects of the majority of the traits indicated that the crosses which had high *sca* effect were having low x low or high x high *gca* parental combination, indicating a genetic interaction of the dominance x dominance and additive x additive types. However, high x low, low x high combinations were also seen.

From these studies it could be concluded that the lines CMS4546A, CMS-103A and testers R-64NB, R-12 NB have good general combining ability for yield and oil content and, may be utilized in breeding programme. The line R-3NB needs further evaluation for protein content. The hybrid CMS-103 A X R-64NB and CMS 4546 X R-64 NB which exhibited the highest sca effect for plant yield and oil content, respectively needs to be critically evaluated over different seasons and locations to confirm their superiority and stability.

Acknowledgement: This work was carried out under the NATP mission mode project on the hybrid crops (Sunflower), Raichur Centre. The authors are thankful to the ICAR, New Delhi for the financial assistance.

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J. Oilseeds Res., **23**(2) : 292-294 (2006)

Short communication

Heterosis breeding in sesame, *Sesamum indicum* L.

K.P. Prajapati, K.M. Patel, C.J. Patel and D.A. Thakker

Main Castor and Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar-385 506, Gujarat

(Received: March, 2005; Revised: August, 2005; Accepted: December, 2005)

Sesame, *Sesamum indicum* syn. *S. orientale* (L.) is one of the most important ancient edible oilseeds crop of India. India is the largest producer and exporter of sesame in the world. However, its productivity is low due to its cultivation under rainfed situations on marginal lands with low input application and also use of land races/local cultivars. Though, the crop is grown since long time, heterosis has not been exploited in this crop. Therefore, to have a quantum jump in yield, exploitation of hybrid vigour and heterosis breeding is gaining importance, for which is necessary to reshuffle the genes by crossing and study the heterotic effects in F_1. Therefore, a study was under taken to determine the magnitude of heterosis in sesame.

The materials comprised of 10 parents *viz.*, AT 103, GT 1, PT 64, PT 65, Mrug 1, TC 25, Pb. Til 1,Vinayak, TMV 3 and C 1013 and their 45 F1s (excluding reciprocals) obtained through diallel cross. The experimental materials were evaluated in Completely Randomized Block Design with three replications, using GT 2 as a standard check during *kharif*, 2002. Each genotypes were sown in one row of 5 m length with 45 x 15 cm spacing. The recommended agronomical practices and plant protection measures were adopted for raising the good crop. The observations were recorded on five randomly selected plants in each plot for 10 characters.

The analysis of variance revealed highly significant differences among genotypes and hybrids suggesting the existence of considerable amount of genetic variability in the experimental materials (Table 1). The average performance of the hybrids was different from the parents as evident from the significant parents vs. hybrids source of variation for use of the characters, except days to 50% flowering, number of capsules/plant, seeds/capsule and oil content, indicating high heterotic response in the materials.

For days to 50% flowering significant negative heterosis was recorded, which is desirable for earliness. It was observed that crosses showing negative heterosis for 50% flowering did not always exhibit negative heterosis for days to maturity, which revealed complex nature of gene action. The hybrids, AT 103 x TMV 3 and AT 103 x GT 1 exhibited dwarfness, indicating that, crosses involving AT 103, GT 1 and TMV 3 as one of the parent showed dwarfness, and their use as a potential donor parent for the development of dwarf varieties is possible. Significant heterosis in desired direction was also recorded for various yield attributing traits. The hybrids showing the highest heterosis with respect to each of these traits are presented in Table 2.

The heterobeltiosis was low (22.8%) for number of branches per plant, whereas, relative heterosis was high (70.6%) and standard heterosis (163.2%) was observed highest in magnitude for this trait. Similar results were obtained by Shinde *et al.* (1993). In case of number of capsules per plant, the relative heterosis (24.3%), heterobeltiosis (13.8%) and standard heterosis (26.0%) were low in magnitude.

In present study, for seed yield, 29 hybrids depicted significant positive relative heterosis, 12 exhibited significant positive heterobeltiosis, while significant positive standard heterosis was exhibited by 28 hybrids. A study of standard heterosis for seed yield and its component traits revealed that the hybrid TMV 3 x C 1013 (116.4%) expressing the highest standard heterosis, also manifested high standard heterotic effects for yield attributing traits *viz.*, number of branches/plant, number of capsules/plant and oil content. Similar trend was observed in other high standard heterotic hybrids *viz.*, PT 64 x Pb. Til 1(92.9%) and PT 64 x TC 25 (92.1%). These hybrids were heterotic over GT 2 for various yield attributing components *viz.*, number of capsule/plant, oil content and days to 50% flowering. High association among these attributes as well as yield have been reported as in case "combinational heterosis" (Herberge, 1952; Krishnaiah *et al.*, 2003).

The rest of characters like capsule length, seeds/capsule, 1000-seed weight and oil content showed low to medium amount of relative heterosis, heterobeltiosis and standard heterosis in desired direction. In this study, in almost all other characters variable number of hybrids depicted heterosis in both positive and negative direction, indicating that genes with negative as well as positive effects were dominant.

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

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height	Number of branches/ plant	Number of capsules/ plant	Capsule length	Seeds/ capsule	1000 seed weight	Oil content	Seed yield/ plant
Replication	2	2.6	98.9**	630.0**	0.8	90.7**	0.3**	405.4**	0.0	5.0	5.0
Genotype	54	22.9**	7.9**	321.5**	3.5**	241.3**	0.2**	67.1**	0.3**	7.1**	41.5**
Parents	9	36.2**	9.8**	608.1**	5.8**	156.8**	0.3**	101.4**	0.4**	11.3**	41.2**
Hybrids	44	20.6**	7.4**	229.3**	3.1**	263.2**	0.1**	61.4**	0.3**	6.4**	38.7**
Parents vs. Hybrids	1	3.6	12.0*	1801.3**	3.4**	38.3	0.2*	8.7	0.5**	0.2	164.5**
Error	108	1.9	2.0	68.2	0.3	16.7	0.03	15.6	0.03	1.8	2.8
SEm ±		0.8	0.8	4.8	0.3	2.4	0.1	2.3	0.1	0.8	1.0
CD (P= 0.05)		2.2	2.3	13.4	0.9	6.6	0.3	6.4	0.3	2.2	2.7

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

Table 2 Summary of three best hybrids and number of crosses showing significant heterosis in desired direction and range of heterosis (%) with respect to ten characters in sesame

Characters	Best heterotic crosses and range of heterosis (%) over						No of crosses showing significant	
	Mid parent		Better parent		Check (GT 2)		Hetero-beltiosis	Standard heterosis
Days to 50% flowering	PT 65 x Pb.Til 1 Vinayak x TMV 3 TC 25 x Pb Til 1	(-7.5 to 8.7)	Mrug 1 x TC25 TC 25 x C 1013 TC 25 x Pb Til 1	(-4.0 to 18.8)	AT 103 x GT 1 AT 103 x Pb Til 1 TC 25 x Pb Til 1	(-20.6 to 26.1)	00	00
Days to maturity	Mrug 1 x Vinayak PT 65 x Vinayak AT 103 x PT 64	(-3.3 to 2.5)	Mrug 1 x Vinayak PT 65 x Vinayak PT 64 x Vinayak	(-2.4 to 3.2)	AT 103 x Pb Til 1 GT 1 x C 1013 T 1 x Pb Ti l 1	(-3.1 to 4.9)	02	05
Plant height	AT 103 x TMV 3 PT 65 x Pb.Til. 1 AT 103 x PT 65	(-4.3 to 23.1)	AT 103 x GT 1	(-0.3 to 29.0)	AT 103 x GT 1 GT 1 x Pb Ti l 1 AT 103 x TMV 3	(-9.6 to 16.6)	00	01
Number of branches/ plant	PT 64 x C 1013 GT 1 x PT 64 AT 103 x PT 64	(-18.5 to 70.6)	TMV 3 x C 1013 Pb.Til. 1 x Vinayak GT 1 x PT 64	(-29.9 to 22.8)	TMV 3 x C 1013 GT 1 x TMV 3 AT 103 x TMV 3	(0.00 to 163.2)	01	33
Number of capsules/ plant	PT 64 x PT 65 PT 64 x Mrug 1 PT 64 x TC 25	(-28.9 to 24.3)	Pb. Til 1 x Vinayak PT 64 x Pb. Til 1 TMV 3 x C 1013	(-27.9 to 13.8)	TMV 3 x C 1013 GT 1 x TMV 3 AT 103 x TMV 3	(-31.1 to 26.0)	05	15
Capsule length	GT 1 x TMV 3 PT 64 x Pb.Til. 1 Pb.Til. 1 x C 1013	(-11.6 to 14.3)	Pb.Til. 1 x C 1013 TMV 3 x C 1013 Pb.Til. 1 x Vinayak	(-16.1 to 7.7)	PT 64 x TC 25 AT 103 x PT 64 AT 103 x TC 25	(-18.9 to 17.5)	00	08
Seeds/capsule	AT 103 x TMV 3 GT 1 x TMV 3 TMV 3 x C 1013	(-10.5 to 14.3)	Pb.Til. 1 x C 1013 AT 103 x PT 64 TMV 3 x C 1013	(-13.9 to 3.8)	AT 103 x PT 64 AT 103 x GT 1 AT 103 x TC 25	(-10.3 to 16.7)	00	13
1000- seed weight	PT 64 x C 1013 AT 103 x TMV 3 TMV 3 x C 1013	(-6.7 to20.5)	AT 103 x TC 25 PT 65 x Mrug 1 Mrug 1 x Pb.Til 1	(-14.7 to 10.4)	AT 103 x PT 64 AT 103 x TC 25 PT 64 x Pb. Til 1	(-11.2 to 26.7)	04	24
Oil content	Pb.Til. 1 x C 1013 TMV 3 x C 1013 GT 1 x Pb Ti l 1	(-6.2 to 6.9)	Pb.Til. 1 x C 1013 TC 25 x Pb Til 1 GT 1 x TC 25	(-10.7 to 5.0)	TMV 3 x C 1013 PT 64 x PT 65 PT 64 x TMV 3	(-2.5 to11.0)	01	18
Seed yield/plant	TMV 3 x C 1013 AT 103 x Vinayak GT 1 xPb.Til 1	(-23.9 to 71.6)	GT 1 xPb.Til 1 AT 103 x Pb Til 1 AT 103 x Vinayak	(-40.3 to 65.5)	TMV 3 x C 1013 PT 64 x Pb. Til 1 PT 64 x TC 25	(-29.1 to 116.4)	12	28

*Figures in parenthesis are range of heterosis (%)

Most heterotic hybrid for seed yield/plant was TMV 3 x C 1013. It recorded also high heterosis in desired direction for many yield contributing traits. Such hybrid can be useful for large scale cultivation in future (Dusane *et al.*, 2002) if give stable yield over years and seasons.

Heterosis in sesame was studied in a set of 10 x 10 diallel crosses excluding reciprocals. The analysis of variance indicated highly significant differences for all the traits, suggesting the presence of sufficient genetic variability in the material studied. The magnitude of heterosis varied from trait to trait. The amount of heterosis was high for seed yield and number of branches/plant, whereas, for days to 50% flowering, days to maturity, plant height, number of capsules/plant, capsule length, seeds/capsule, 1000-seed weight and oil content had law magnitude of heterosis. The hybrid TMV 3 x C 1013 manifested highest economic heterosis (116.4%) and relative heterosis (71.6%) for seed yield/plant. This cross also had positive economic heterosis for number of branches/plant (163.2%), number of capsules/plant (26.0%) and oil content (11.0%).

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J. Oilseeds Res., **23**(2) : 295-296 (2006)

Short communication

Genetic divergence in sesame, *Sesamum indicum* L.

N. Sudhakar, O. Sridevi and P.M. Salimath

Dept. of Genetics and Plant Breeding, College of Agriculture, University of Agril. Sciences, Dharwad-580 005, Karnataka

(Received: September, 2005; Revised: March, 2006; Accepted: June, 2006)

Sesame, *Sesamum indicum* L. is an important oilseed crop of tropical and sub-tropical region. Improvement in yield is normally attained through exploitation of the genetically diverse parents in breeding programmes. For identifying such diverse parents for crossing, multivariate analysis by means of Mahalanobis's D^2 statistic has been used in several crops. The present study has been undertaken with 62 sesame genotypes to understand genetic divergence and the characters contributing for it by using D^2 statistics.

Sixty two sesame genotypes were sown during *kharif*, 2002 in Randomized Block Design with three replications. Each genotype was sown in single row of 4 m length at a distance of 30 cm between the rows and 10 cm between the plants within the rows. Observations on yield and yield contributing traits were recorded on five randomly selected plants of each genotype in each replication (Table 1). Multivariate analysis was done as per Mahalanobis's D^2 statistics described by Rao (1952) and the genotypes were grouped into different clusters following Tocher's method. Contribution of each character for genetic divergence was estimated from the number of times each character appeared in first rank.

Based on the D^2 values the genotypes were grouped into 13 different clusters (Table 1). Among them, cluster-I was the largest, which comprised of 31 genotypes followed by cluster-II (13), cluster-VI (16) and cluster-X (3). The remaining clusters had one genotype each. The varieties belonging to diverse geographic were grouped into one cluster and vice-versa. Similar observations have been reported by Ganesh and Thangavelu (1996); Manivannan and Nadarajan (1996); Swain and Dikshit (1997), Johnjoel *et al.* (1998) and Gupta *et al.* (2001). The absence of relationship between genetic diversity and geographical diversity suggest that forces other than geographic origin such as exchange of breeding material, genetic drift, variations, natural and artificial selection are responsible for diversity as reported by Murthy and Arunachalam (1966) and Shariff and Shivashankar (1992).

The intra cluster D^2 value ranged from 0.00 (cluster-III, IV, V, VII, IX, XI, XII and XIII) to 23.091 while intercluster values from 10.117 (cluster-IV and cluster-V) to 76.705 (cluster-VI and cluster-VII) (Table 2).

Contribution of each character towards genetic divergence has been estimated (Table 3). It has been observed that number of capsules/plant contributed the maximum of 43.57% towards genetic divergence followed by number of seeds/capsule (30.57%), days to maturity (14.60%), days to 50% flowering (7.56%), plant height (3.20%) and seed yield/plant (0.42%). Similar observations have been recorded by Alarmelu and Ramanathan (1998) and Solanki and Gupta (2002).

Table 1 Cluster composition of 62 sesame genotypes

Cluster	Total No. of genotypes	Genotypes
I	31	Chitradurga Local-1 (white), IVT-3, Bijapur Local, SI-1659, SI-1577, DS-9, TRS-9, DS-14, PSR-1967, Gulbarga Local-3, DS-7, DCB-1855, DORS-2, IVT-16, DS-16, Bankapur Local, DCB-1858, NKD-1140, SI-2786, IVT-15, IVT-1, TRS-16, NKD-1163, Gulbarga Local-10, Hosadurga Local, SI-2525, PSR-1987, T2A/96-612, IVT-5, Gulbarga Local-4, SI-2636
II	13	SI-2595/2, TRS-11, Phule-Til, IVT-20, PSR-2949, Gulbarga Local-8, SI-2725, DS-13 (white), IVT-21, Gulbarga Local-5, Gulbarga Local-1, BS-13 (black), PSR-1874
III	1	IVT-10
IV	1	IVT-15
V	1	PSR-1996
VI	6	IVT-7, DS-1, DCB-1885, DS-10, IVT-2, E-8
VII	1	Chitradurga Local (black)
VIII	1	Chitradurga Local-2 (white)
IX	1	PSR-1998
X	3	DS-15, Davanagere Local-1, MT-15
XI	1	Davanagere Local-2
XII	1	PSR-1774
XIII	1	DCB-1864

Table 2 Intra and inter cluster D2 values along with their D values in parenthesis for 13 clusters formed by 62 genotypes in sesame

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I	22.278 (4.71)	40.834 (6.39)	29.685 (5.44)	29.946 (5.47)	35.495 (5.95)	75.007 (8.66)	33.354 (5.77)	34.584 (5.88)	30.628 (5.53)	58.208 (7.62)	39.304 (6.26)	50.943 (7.13)	60.771 (7.79)
II		21.465 (4.63)	33.451 (5.78)	43.893 (6.62)	45.626 (6.75)	42.443 (6.51)	45.530 (6.74)	30.339 (5.50)	35.664 (5.97)	36.863 (6.07)	37.254 (6.10)	45.506 (6.74)	51.762 (7.19)
III			0.000 (0.00)	31.796 (5.63)	31.956 (5.65)	62.250 (7.88)	28.765 (5.36)	36.836 (6.06)	36.983 (6.08)	38.064 (6.16)	48.158 (6.93)	34.779 (5.89)	53.826 (7.33)
IV				0.000 (0.00)	10.117 (3.18)	76.244 (8.73)	18.790 (4.33)	51.293 (7.16)	17.644 (4.20)	52.875 (7.27)	33.697 (5.80)	33.133 (5.75)	38.378 (7.33)
V					0.000 (0.00)	75.831 (8.70)	13.151 (3.62)	56.412 (7.51)	22.724 (4.76)	48.718, (6.97)	40.573 (6.36)	24.838 (4.98)	33.272 (5.76)
VI						20.393 (4.51)	76.705 (8.75)	56.927 (7.54)	67.425 (8.21)	42.136 (6.49)	64.461 (8.02)	64.963 (8.05)	67.493 (8.21)
VII							0.000 (0.00)	53.948 (7.34)	27.541 (5.24)	48.009 (6.92)	46.885 (6.84)	27.178 (5.21)	41.341 (6.42)
VIII								0.000 (0.00)	43.966 (6.63)	55.600 (7.45)	42.606 (6.52)	63.793 (7.98)	72.678 (8.52)
IX									0.000 (0.00)	51.369 (7.16)	19.971 (4.46)	38.864 (6.23)	37.109 (6.09)
X										23.091 (4.80)	59.329 (7.70)	32.481 (5.69)	46.223 (6.79)
XI											0.000 (0.00)	53.655 (7.32)	46.392 (6.81)
XII												0.000 (0.00)	27.024 (5.19)
XIII													0.000 (0.00)

Table 3 Contribution of each characters (%) towards divergence

Character	Percentage contribution	Ranking
Days to 50% flowering	7.56	IV
Days to maturity	14.60	III
Plant height	3.20	V
Number of primary branches	0.00	
Number of capsules/plant	43.57	I
Capsule length	0.00	
Number of seeds/capsules	30.57	II
Oil content	0.00	
Seed yield/plant	0.42	VI

Cluster-VI recorded the highest mean values for plant height, number of capsules/plant, number of primary branches, oil content and seed yield/plant. High mean values for capsule length and number of seeds/capsule were recorded by cluster-XII and XIII, respectively.

From the present investigation, the genotypes from distant clusters to be considered for formulating hybridization program. While doing so the genotypes with better mean values of the respective character of the respective cluster means ought to be considered.

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J. Oilseeds Res., **23(2) : 297-300 (2006)**

Short communication

Effect of environment on correlations and path analysis in sesame, *Sesamum indicum* L.

T. Anuradha and G. Lakshmi Kantha Reddy[1]

Agricultural Research Station, Peddapuram-533 437, East-Godavari District, AP

(Received: August, 2004; Revised: October, 2005; Accepted: December, 2005)

Significance of correlation and path coefficient analysis in the breeding programme has been well recognized by plant breeders. However, in sesame most of the studies so far have been confined to single environment only. Since, the inter relationship and path coefficients like other genetic estimates vary from environment to environment and depending on the material under a given set of environmental conditions, a study was undertaken on the correlation coefficients and direct and indirect effects of seed yield on component characters in sesame at 3 different locations in Andhra Pradesh

The material comprised of 71 genotypes of sesame. Experiment was conducted in a Randomized Block Design and replicated twice. Each plot consisted of 2 rows of 4 m. length spaced 30 cm apart. The experiment was conducted during *kharif*, 2001 at three locations *viz.*, Agricultural Research Station, Peddapuram (East Godavari District), Agricultural Research Station, Elamanchili (Visakhapatnam District), and Regional Agricultural Research Station, Jagtial (Karimnagar District). Data were recorded on 10 healthy randomly selected plants on 12 parameters (Table1). Correlations were worked out according to the formulae suggested by Falconer (1964) and path coefficients calculated as per Dewey and Lu (1959).

Correlation of yield and yield attributes at the 3 locations revealed that the traits capsules on primary branches (Jayalakshmi and Raja Reddy 1999; Ashoka Vardhan Reddy *et al.*, 2001) capsules/plant (Singh *et al.*, 1997; Tomar *et al.*, 1999; Sharma and Mandal, 2001), biological yield (Tomars *et al.*,1999; Ashokavardhan Reddy *et al.*, 2001) and harvest Index (Ashokavardhan Reddy *et al.*, 2001) exhibited significant and positive correlation with seed yield at all the 3 locations. As such, they are not influenced by the changes in environmental conditions and are being stably associated. Hence, selection criteria based on these traits can be employed across locations.

The *inter se* correlation across the 3 locations revealed that plant height with capsules/plant, number of primary branches with capsules on primary branches and capsules/plant, capsules on main stem with capsules/plant and harvest index, capsules on primary branches with capsules/plant and biological yield and harvest index exhibited stable association over the environments and as such, emphasis should be relied on them in selection programme.

Further, to identify the effective component of seed yield which showed maximum direct and indirect effects, in addition to correlation coefficients at the 3 locations ,path analysis were also taken up (Table 2).

The results suggested that biological yield (Ashokavardhan Reddy *et al.*, 2001) and harvest Index (Ashokavardhan Reddy *et al.*, 2001; Sharma and Mandal, 2001) exerted high magnitude of direct effects on seed yield at all the three locations. Indirect effects of these traits were also high and positive with most of the traits along with high positive correlation, with seed yield. As such, selection criteria can be framed by improvement of yield by way of direct selection for biological yield and harvest index at all the three locations as they are stable.

[1] Associate Dean, Agricultural College, Bapatla-522 101, Guntur Dt., A.P.

Table 1 Phenotypic correlations coefficients for yield and yield traits among 71 genotypes of sesame at 3 locations

Character	Loc-ations	Days to maturity	No.of primary branches	Capsules on main stem	Capsules on primary branches	Capsules/ plant	Capsules length	Seeds/ capsule	1000 seed weight	Biological yield	Harvest index (%)	Seed yield/ plant
Plant height	P	0.0527	0.0232	0.5477**	0.0739	0.3193**	0.1708	0.2304*	0.0242	0.3770**	0.1261	0.3229**
	E	0.0882	0.3381**	0.1712	0.3550**	0.3304**	0.1148	-0.0313	0.0527	-0.3309**	0.1901	0.0546
	J	0.6560**	0.4957**	0.7370**	0.8104**	0.7588**	0.3317**	-0.0145	-0.1404	0.4174**	0.1708	0.3887**
Days to maturity	P		-0.1739	-0.2552*	-0.2974**	-0.3653**	0.0302	-0.1924	-0.1205	0.0061	-0.500	-0.3291**
	E		-0.1812	-0.1604	-0.1434	-0.1631	0.2540**	-0.2266*	-0.0874	0.0606	-0.0236	0.0703
	J		0.5721**	0.7483**	0.7773*	0.8296**	0.2341*	0.0148	-0.2153*	0.6787**	0.3746**	0.7321**
Number of Primary branches	P			-0.1845	0.7739**	0.6936**	0.0907	-0.0441	-0.0301	0.5704**	0.0112	0.4782**
	E			0.0335	0.5068**	0.4034**	-0.2032*	0.0793	-0.0824	-0.1981	0.2931*	0.1188
	J			0.4954**	0.5927**	0.6212**	0.1198	0.0178	-0.1156	0.5094**	0.1183	0.4569**
Capsules on main stem	P				-0.0328	0.3867**	0.1828	0.1987*	0.2232*	0.0865	0.2022*	0.1501
	E				0.5867**	0.7788**	0.3649**	-0.1554	0.1697	0.1510	0.2795**	0.4016**
	J				0.8070**	0.8806**	0.2149*	0.0208	-0.1167	0.3979**	0.2783**	0.4480**
Capsules on primary branches	P					0.8731**	0.0505	0.0264	0.0493	0.6313**	0.0892	0.5751**
	E					0.9649**	0.2653**	-0.0960	-0.2940**	0.2114*	0.4038**	0.5253**
	J					0.9353**	0.2674**	0.0537	-0.1615	0.5648**	0.2513*	0.5611**
Capsules/ plant	P						0.1628	0.1767	0.1341	0.6386**	0.1958*	0.6275**
	E						0.3238**	-0.1248	0.2828**	0.2127*	0.4035**	0.5348**
	J						0.2268*	-0.0057	-0.1800	0.5392**	0.3026**	0.5710**
Capsule length	P							0.4231**	0.3346**	0.0280	0.24449*	0.1620
	E							-0.0202	0.0506	0.1210	0.1393	0.2483*
	J							0.1246	0.1681	0.0545	-0.1517	-0.0310
Seeds/ Capsule	P								0.2157	-0.0219	0.2916**	0.1475
	E								-0.0953	-0.1963	0.0302	-0.0947
	J								0.1707	-0.0939	0.1216	-0.0601
1000 seed weight	P									-0.1274	0.1947*	0.0280
	E									0.0413	0.2426*	0.1855
	J									-0.2985**	-0.0654	0.2408*
Biological yield	P										-0.0975	0.7227**
	E										0.0112	0.6200**
	J										0.1475	0.8020**
Harvest index (%)	P											0.5805**
	E											0.6530**
	J											0.6153**

P = Peddapuram; E = Elamanchili; J = Jagital * Significant at 5% level; ** Significant at 1% level

Table 2 Direct and indirect effects of yield traits in seed yield for 71 genotypes of sesame at 3 locations

Character		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 (%)
Plant height	P	-0.0449	-0.0024	-0.0010	-0.0246	-0.0033	-0.0143	-0.007	-0.0091	-0.0011	-0.0169	-0.0057
	E	0.1333	0.0118	0.0451	0.0228	0.0473	0.0440	0.0153	-0.0042	0.0070	-0.0441	0.0253
	J	-0.1004	-0.0659	-0.0498	-0.0740	-0.0814	-0.0762	-0.0333	0.0015	0.0141	-0.0419	-0.0172
Day to Maturity	P	0.00020	-0.0002	0.000	0.000	0.000	0.0001	0.000	0.000	0.000	0.000	0.0001
	E	-0.0098	-0.1115	0.0202	0.0179	0.0160	0.0182	-0.0283	0.0253	0.0097	-0.0068	0.0026
	J	0.1081	0.1647	0.0942	0.1233	0.1281	0.1367	0.0386	-0.0024	-0.0355	0.1118	0.0617
Number primary branches	P	-0.0001	0.0009	-0.0053	0.0010	-0.0041	-0.0036	-0.0005	0.0002	0.0002	-0.0030	-0.0001
	E	0.0010	-0.0005	0.0028	0.0001	0.0014	0.0011	-0.0006	0.0002	0.0002	-0.0006	0.0008
	J	0.0179	0.0207	0.0362	0.0179	0.0214	0.0225	0.0043	0.0006	-0.0042	0.0184	0.0043
Capsules on main stem	P	-0.0232	0.008	0.0078	-0.0425	0.0014	-0.0164	-0.0078	-0.0084	-0.0095	-0.0037	-0.0086
	E	-0.0045	0.0042	-0.0009	-0.0262	-0.0154	-0.0204	-0.0095	0.0041	-0.0044	-0.0040	-0.0073
	J	-0.0075	-0.0077	-0.0051	-0.0102	-0.0083	-0.0090	-0.0022	-0.0002	0.0012	-0.0041	-0.0028
Capsules on primary branch	P	-0.0010	0.0039	-0.0102	0.0004	-0.0132	-0.0115	-0.0007	-0.0003	-0.0007	-0.0083	-0.0012
	E	-0.0523	0.0211	-0.0747	-0.0864	-0.1473	-0.1421	-0.0391	0.0141	-0.0433	-0.0311	-0.0595
	J	0.1158	0.1111	0.0847	0.1153	0.1429	0.1337	0.0382	0.0077	-0.0231	0.0807	0.0359
Capsules/ Plant	P	0.0108	-0.0124	0.0236	0.0131	-0.0296	0.0340	0.0055	0.0060	0.0046	0.0267	0.0066
	E	0.0818	-0.0404	0.0998	0.1927	0.2387	0.2474	0.0801	-0.0309	0.0700	0.0526	0.0998
	J	-0.0968	-0.1059	-0.0793	0.1124	-0.1194	-0.1276	-0.0289	-0.0007	0.0230	-0.0688	-0.0386
Capsule Length	P	-0.0019	-0.0003	-0.0010	-0.0020	-0.0006	-0.0018	-0.0110	-0.0047	-0.0037	-0.0003	-0.0027
	E	0.0084	0.0186	-0.0149	0.0268	0.0195	0.0238	0.0734	-0.0015	0.0037	0.0089	0.0102
	J	0.0038	0.0027	0.0014	0.0025	0.0031	0.0026	0.0115	0.0014	0.0019	0.0006	-0.0017
Seeds/ Capsule	P	-0.0036	0.0034	0.0008	-0.0035	-0.0005	-0.0031	-0.0074	-0.0175	-0.0038	0.0004	-0.0051
	E	-0.0001	-0.0009	0.0003	-0.0006	-0.0004	-0.0005	-0.0001	0.0041	-0.0004	-0.0008	0.0001
	J	0.0009	0.0009	-0.0011	-0.0013	-0.0003	-0.0003	-0.0076	-0.0609	-0.0104	0.0057	-0.074
1000 Seed weight	P	0.0003	-0.0016	-0.0004	0.0029	0.0006	0.0017	0.0043	0.0023	0.0128	-0.0016	0.0025
	E	-0.0013	0.0021	-0.0020	-0.0049	-0.0071	-0.0068	-0.0012	0.0023	-0.0241	-0.0010	-0.0059
	J	0.0082	0.0126	0.0067	0.0068	0.0094	0.0105	-0.0098	-0.0100	-0.0584	0.0174	-0.0038
Biological Yield	P	0.3016	0.0049	0.4564	0.0692	0.5051	0.5109	0.0224	-0.0175	-0.1019	0.8001	-0.0780
	E	-0.2120	0.0388	-0.1269	0.0967	0.1354	0.1363	0.0775	-0.1258	0.0265	0.6407	0.0072
	J	0.2542	0.4134	0.3103	0.2423	0.3440	0.3284	0.0322	-0.0512	0.01818	0.6091	0.0898
Harvest Index (%)	P	0.0848	-0.3363	0.0075	0.1360	0.0600	0.1317	0.1647	0.1961	0.1310	-0.656	0.6725
	E	0.1102	-0.0137	0.1699	0.1620	0.2340	0.2338	0.0808	0.0175	0.1406	0.0065	0.5795
	J	0.0846	0.1855	0.0586	0.1378	0.1244	0.1499	-0.0751	0.0662	0.0324	0.0730	0.4951
Correlation with seed yield	P	0.3229**	-0.329**	0.4782**	0.1501	0.5751**	0.6275**	0.1620	0.1475	0.0280	0.7227**	0.5805**
	E	0.0546	-0.0703	0.1188	0.4016**	0.5223**	0.5348**	0.2483*	-0.0947	0.1855	0.6204**	0.6530**
	J	0.3887**	0.7321**	0.4569**	0.4480**	0.5611**	0.5710**	-0.0310	-0.0601	-0.2408*	0.8020**	0.6153**

Residual effect at P = Peddapuram = 0.212; E= Elamanchili = 0.388; J = Jagital=0.2978; * Significant at 5% level; ** Significant at 1% level

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J. Oilseeds Res., **23**(2) : 301-303 (2006)

Short communication

Studies on genetic diversity in safflower, *Carthamus tinctorius* L.

R. Diwakar, N. Sreedhar and N. Mukta[1]

Department of Genetics and Plant Breeding, College of Agriculture, ANG Ranga Agril. University, Rajendranagar, Hyderabad-500 030, AP

(Received: April, 2005; Revised: September, 2005; Accepted: February, 2005)

Safflower traditionally grown as a source of Carthamin dye is now primarily grown as an oilseed crop due to the high quality edible oil obtained from its seed. Study of genetic diversity among a set of genotypes will enable a plant breeder to select suitable parents, which is a crucial factor that determines the success of any hybridization programme.

The experimental material comprised of 60 exotic germplasm accessions and 4 cultivated check varieties of safflower obtained from Safflower Germplasm Management Unit (GMU) of the Directorate of Oilseeds Research, Rajendranagar, Hyderabad. The experiment was carried out during *rabi*, 2003-04 and was sown in Simple Lattice (8 x 8) design with 2 replications. Data were recorded on eight characters *viz.*, days to 50% flowering, plant height, number of effective capitula/plant, number of filled seeds in main capitulum, diameter of main capitulum, 100-seed weight, oil content and seed yield/plant. Clustering of genotypes into different clusters was done by using Euclidean method. Based on D^2 values (Mahalanobis, 1935), average intra and inter cluster distances were calculated as per Euclidean method. Genetic diversity among the 64 genotypes was assessed by D^2 statistic following the procedure given by Rao (1952).

Based on the D^2 analysis, the 60 germplasm accessions and 4 check varieties were grouped into 9 clusters by using Euclidean cluster analysis (Table 1). The magnitude of D^2 values suggested presence of considerable amount of diversity in the experimental material. The pattern of distribution of genotypes into various clusters was at random suggesting that geographical diversity and genetic diversity were not related. Similar results on genetic diversity in safflower were earlier reported by Ranga Rao *et al.* (1980); Patil *et al.* (1991); Dingming *et al.* (1993); Ghongade and Navale (1995) and Venkata Gopinath (2003).

Table 1 Distribution of 64 genotypes of safflower in different clusters

Cluster No.	No. of genotypes	Genotype/check varieties
I	20	GMU 950, 1197, 1251, 1281, 1386, 1791, 1796, 1797, 1805, 1988, 2007, 3121, 4083, 4094, 4119, 4361, 4390, 4391, 4859, 4860
II	1	GMU 4388
III	9	GMU 1306, 1394, 3152, 4092, 4393, 4799, 4800, 5133, 5389
IV	6	GMU 1794, 1815, 3120, 4096, 4392, 5129
V	8	GMU 1383, 2010, 2039, 2040, 4389, 5121, 5125, 5132
VI	4	GMU 4050, 4863, 5131, A-1
VII	8	GMU 1250, 1790, 2001, 4087, 5122, 5151, Bhima, Manjira
VIII	5	GMU 1792, 4063, 4068, 4078, NARI-6
IX	3	GMU 4045, 4073, 4098

The average intra and inter cluster D^2 values are presented in Table 2. Intra cluster values ranged from 0 (cluster II) to 58.76 (cluster VII).

From the inter cluster distances it could be inferred that divergence was least between cluster IV and V (56.35) while, maximum divergence was between cluster II and cluster IX (495.09) followed by cluster IX and cluster VII (384.65) suggesting that genotypes in these clusters could be fully exploited to explore the wide range of heterosis and release good recombinant lines by intermating them in a definite design. Similar results were earlier reported by Patil *et al.* (1991) and Ghongade and Navale (1995). The data on cluster means is presented in Table 3.

[1] Senior Scientist, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP.

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

	I	II	III	IV	V	VI	VII	VIII	IX
I	**39.87**	119.44	65.83	66.58	82.67	78.54	131.51	104.87	209.08
II		**0.00**	192.17	227.94	246.39	194.17	170.44	328.80	495.09
III			**40.28**	72.46	68.32	71.41	122.98	88.41	230.83
IV				**34.11**	56.35	113.76	129.12	90.36	177.99
V					**32.25**	63.03	114.68	81.51	154.88
VI						**37.19**	141.92	81.77	167.16
VII							**58.76**	225.71	384.65
VIII								**35.64**	89.56
IX									**48.64**

Table 3 Cluster means for eight characters of 64 safflower genotypes

Cluster No.	Days to 50% flowering	Plant height (cm)	No. of effective capitula/plant	Diameter of main capitulum (mm)	No. of filled seeds in main capitulum	100 seed weight (g)	Oil content (%)	Seed yield/plant (g)
I	79.57	68.82	16.66	20.66	22.71	5.25	26.41	11.83
II	69.00	61.30	17.30	21.35	19.45	5.50	29.75	15.75
III	83.33	65.17	21.11	17.68	16.63	5.25	26.00	12.96
IV	85.66	69.23	18.08	22.27	29.66	4.54	27.60	15.65
V	86.06	71.06	18.46	22.01	21.90	6.01	26.90	19.52
VI	81.25	75.32	15.90	18.61	11.42	6.55	25.68	14.62
VII	80.75	72.61	23.43	21.63	25.90	5.33	26.74	30.72
VIII	86.10	80.90	14.93	18.03	13.60	4.34	26.52	6.90
IX	87.66	94.40	12.00	23.08	20.91	5.45	28.50	6.69
Mean	82.46	71.53	18.10	20.48	21.25	5.31	26.68	15.28

The data revealed that considerable differences existed among the clusters. Genotypes in cluster VII were early to flower (80.75 days) and recorded the highest seed yield/plant (30.72 g) as compared to the general mean (82.46 days). Genotypes in cluster IX were late in flowering (87.66 days) and recorded the lowest seed yield/plant (6.69 g) as compared to the general mean (15.28 g). The results indicated that seed yield would decrease considerably as the flowering period increased. Similar findings were reported by Venkata Gopinath (2003).

Based on the present study, GMU 4045 (Cluster IX) and GMU 4388 (Cluster II) could be used as parental lines for improving the oil content in safflower in future breeding programmes.

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J. Oilseeds Res., 23(2) : 304-305 (2006)

Short communication

Variability and character association for various quantitative characters in safflower, *Carthamus tinctorius* L.

P.K. Jagtap[1], B.M. Joshi[2], S.B. Ghuge and S.S. Jawanjal

Department of Genetics and Plant Breeding, Marathwada Agricultural University, Parbhani-431 402, MS

(Received: February, 2005; Revised: September, 2005; Accepted: December, 2005)

The area in India under safflower, *Carthamus tinctorius* L. was 4.03 lakh ha with production of 2 lakh tonnes and average productivity of only 465 kg/ha. The genetic male sterility system in safflower has helpful in heterosis exploitation by developing large number of potential hybrids which in turn greatly facilitated in generation of genetic variability. The knowledge of genetic variability provides information on the pattern of character directly or indirectly with seed yield. Similarly the variability parameters helped to formulate the breeding programme. Therefore, the present investigation was undertaken to assess the genetic variation among the newly developed hybrids of safflower and the association of characters, its relation with seed yield directly or indirectly.

Ten hybrids including two checks *viz.*, Sharda and Annegiri-1 were grown in a Randomized Block Design with three replications in *rabi* season of 2003-2004 under irrigated conditions at the Experimental Farm of Department of Genetics and Plant Breeding, Marathwada Agricultural University, Parbhani (M.S.). The single row of 5 m length was sown following 45 and 20 cm spacing between and within rows respectively. Twelve traits were measured by selecting 25 plants in each genotypes. The statistical analysis was performed following the standard procedure.

The analysis of variance showed that the genotypes differed significantly among themselves for all the characters indicating the presence of adequate variability. A wide range was observed for almost all the characters excluding oil content (%) and test weight (g). In general, the phenotypic coefficient of variation (PCV) were slightly higher than their corresponding genotypic coefficient of variation (GCV) due to the environmental influence (Table 1).

Table 1 *Parameters of genetic variability for yield and yield contributing characters in safflower*

Character	Range	General mean	Variance (Mean sum of square)	GCV (%)	PCV (%)	Heritability (%)	Genetic advance	EGA (%)	Genotypes correlation of different characters with seed yield
Days to 50 % flowering	88.66-97.66	92.35	28.84*	2.69	4.40	37.5	3.14	3.40	0.424
Days to maturity	128.50-140.33	135.92	63.54**	2.94	4.13	50.6	5.86	4.31	0.624
Plant height (cm)	70.18-102.43	83.87	466.94**	14.86	14.90	99.5	25.61	30.53	0.807**
Number of primary branches/plant	6.08-10.86	8.69	7.28**	17.49	18.77	86.8	2.92	33.60	0.657*
Number of secondary branches/plant	11.17-22.10	16.13	48.53**	24.59	25.59	92.4	7.86	48.72	0.262
Number of capitula/plant	19.43-32.63	28.35	54.06**	14.70	15.50	90.0	8.15	28.74	0.991**
Number of seeds/capitulum	29.73-45.60	39.79	82.58**	12.97	13.61	90.7	10.12	25.43	0.959**
Test weight (g)	4.80-5.40	5.05	0.14*	3.46	5.88	34.7	0.21	4.15	0.231
Oil content (%)	27.83-32.33	30.37	8.09**	4.80	6.46	55.2	2.23	7.34	-0.955**
Harvest index (%)	25.88-32.22	28.89	12.53**	6.73	7.72	75.9	3.49	12.08	0.094
Volume wt (g/l)	537.73-605.73	572.54	1899.1**	4.30	4.57	88.5	47.75	8.30	0.956**
Seed yield/plant (g)	28.46-41.06	35.59	53.97**	11.23	13.19	72.4	7.00	19.66	1.000

*, ** Significant at 5 and 1 per cent

[1] & 2 M.Sc. (Ag.) Students

The high estimates of heritability coupled with higher genetic advance as per cent of mean for plant height (cm), number of primary branches/plant, number of secondary branches/plant, number capitula/plant, number of capitulum/plant, number of seeds/capitulum and seed yield/plant indicated that the heritable variation of different traits was attributed to additive gene effects, thus selection may be effective for these trails. The traits are in consonance with the findings of Makne *et al.* (1985). High heritability with low genetic advance for days to 50% flowering, days to maturity, test weight (g), oil content (%), harvest index (%) and volume weight (g/l) was indicative of non additive gene action and selection for such traits become difficult as the high heritability in these traits is being exhibited due to favorable influence of the environment rather than genotypes. Similar observations were also reported by Lakha *et al.* (1992). The association between these characters and seed yield revealed that the plant height, primary branches, capitula/plant, seed/capitulum and volume weight had strong positive association with seed yield. Similar association studies were exported by Malleshappa *et al.* (1989). The oil content exhibited negative correlation with yield. the negative correlation of oil content with test weight indicating the bolder seed size with less oil content. These observations were similar to that of Satyavathi *et al.* (2000) in mustard. The path analysis (Table 2) revealed that the volume height (g/l) and number of capitulum/plant were the most important characters contributing directly to yield. Kubsad *et al.* (2000) also reported importance of these characters to seed yield directly. The residual factor (0.032) explained that variables studied were showing high genotypic variability. The reason seem to be a very high and significant correlation of plant height (cm), number of primary branches/plant, number of capitulum/plant, number of seeds/capitulum and volume height (g/l).

Table 2 Direct (diagonal) and indirect (off diagonal) effects of different characters on yield in safflower at genotypic level

Characters	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of *primary* branches/ plant	No. of *secondary* branches/ plant	No. of capitula/ plant	No. of seeds/ capitulum	Test weight (g)	Oil content (%)	Harvest index (%)	Vol. weight (g/l)	Genotypic *correlation* with seed yield/plant (g)
Days to 50 % flowering	**0.039**	-0.004	-0.267	-0.028	-0.016	0.332	-0.132	-0.045	0.133	0.001	0.411	0.424
Days to maturity	0.006	**-0.025**	-0.188	-0.057	-0.007	0.491	-0.192	-0.020	0.199	0.000	0.417	0.624
Plant height (cm)	0.026	-0.012	**-0.403**	-0.060	-0.006	0.541	-0.263	-0.033	0.331	0.002	0.684	0.807
No. of primary branches/plant	0.012	-0.015	-0.253	**-0.096**	-0.023	0.448	-0.187	-0.009	0.247	0.001	0.532	0.657
No. of secondary branches/plant	0.020	-0.006	-0.071	-0.069	**-0.032**	0.167	-0.049	-0.016	0.097	0.001	0.220	0.262
Number of capitula/plant	0.018	-0.017	-0.308	-0.061	-0.008	**0.709**	-0.343	-0.011	0.328	0.004	0.680	0.991
Number of seeds/capitulum	0.015	-0.013	-0.296	-0.050	-0.004	0.679	**-0.358**	-0.006	0.319	-0.002	0.675	0.959
Test weight (g)	0.031	-0.009	-0.233	-0.015	-0.009	0.131	-0.039	**-0.057**	0.131	-0.002	0.302	0.231
Oil content (%)	-0.015	0.014	0.374	0.067	0.009	-0.652	0.320	0.021	**-0.357**	0.000	-0.736	-0.955
Harvest index (%)	0.007	-0.001	-0.062	-0.005	-0.002	0.179	-0.068	0.023	-0.005	**0.003**	0.025	0.094
Volume wt. (g/l)	0.022	-0.014	-0.371	-0.069	-0.009	0.648	-0.325	-0.023	0.353	0.000	**0.744**	0.956

Residual effect = 0.032

Therefore it is concluded from the present investigation that the F_3 progenies of the crosses MS 11 x A_2, Selection 7x GMU 1751, CTH 25 x JLSF 325 and MS 11 x GMU 1735 should be viewed by concentrating on characters like branches and capitulum/plant, seeds/capitula, test weight and volume weight for better improvement of safflower.

Genetic variability among the ten hybrids of safflower including two checks was assessed using the standard procedure. The genotypes differed significantly indicating presence of adequate variability. A wide range of variation with slightly higher phenotypic coefficient of variation was observed in almost all the characters excluding oil content (%). The high heritability coupled with higher genetic advance was attributed to additive gene action useful in selecting same genotypes for characters under study. Oil content exhibited negative correlation with seed yield. There was a least influence of environmental effects on the characters under study.

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J. Oilseeds Res., **23**(2) : 306-307 (2006)

Short communication

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

Vivek Singh, M.P. Chauhan, K. Kumar and R.B. Singh

Dept. of Genetics and Plant Breeding, N.D. University of Agriculture & Technology, Kumarganj, Faizabad-224 229, UP

(Received: November, 2004; Revised: March, 2006; Accepted: June, 2006)

Linseed is grown for seed and fibre. Besides rich source of oil, protein, minerals and vitamins, it is good source of calcium and phosphorus. The present study has been undertaken to know the type of gene action governing seed yield and its component traits and to identify the parents and crosses which could be exploited in future breeding programmes.

Ten diverse lines/varieties were crossed with two testers during *rabi*, 2002-03. The resulting 20 hybrids along with 12 parents (10 lines + 2 testers) were evaluated in a Randomized Block Design with three replications. The entries were sown in a single row of 2 m length with inter and intra-row spacing of 30 cm and 10 cm, respectively. All recommended agronomic practices were adopted in order to raise normal crop. Observations on five randomly selected plants were recorded for 10 traits and their mean values were used for statistical analysis. The analysis of variance for general and specific combining ability was done as per standard procedure (Kempthorne, 1957).

Significant differences among genotypes (parents and crosses) for all the traits were observed. Mean squares due to lines were significant for all the traits except plant height, biological yield/plant and harvest index and due to testers for plant height, capsules/plant, seed yield/plant and 1000-seed weight. Variances due to line x tester were significant for all the characters, suggesting the presence of non-additive gene effect for these traits. Similar findings for these traits were also reported by Ratnaparkhi *et al.* (1998) and Kumar *et al.* (2000) while predominance of additive genetic variance was reported for plant height and 1000-seed weight (Mahto and Rahman, 1998).

Table 1 ANOVA for 10 characters in parents and hybrids of a L x T set in Linseed

Source of variation	Degree of freedom	Days to 50% flowering	Days to maturity	Plant height (cm)	Secondary branches / plant	Capsules / plant	Seeds/ capsule	Seed yield/ plant (g)	1000-seed weight (g)	Biological yield/ plant (g)	Harvest index (%)
Replications	2	0.34	5.06	6.38	0.002	0.95	0.03	0.009	0.04	0.01	0.73
Treatments	31	20.82**	130.44**	123.56**	4.02**	228.69**	1.56**	0.67**	2.14**	5.32**	30.27**
Parents	11	41.27**	165.48**	124.45**	3.58**	197.82**	0.92**	0.62**	2.15**	6.92**	31.49**
Crosses	19	6.84**	110.87**	76.08**	4.49**	258.33**	2.02**	0.71**	2.24**	3.48**	26.32**
Parents Vs Crosses	1	60.90**	117.00**	1015.55**	0.003	4.99	0.04	0.39**	0.004	22.77**	3.89*
Lines	9	10.47**	202.79**	81.45	8.17**	428.2*	3.62**	1.17*	4.29**	4.13	40.85
Testers	1	11.18	1.66	400.23**	0.58	602.6*	0.12	3.62**	4.89**	3.56	11.75
L X T	9	2.72*	31.08**	34.69**	1.23**	117.06**	0.63**	0.32**	0.45**	2.81**	13.42**
Error	62	1.29	4.88	3.88	0.08	4.47	0.05	0.01	0.42	0.19	0.59

Genotypes having significant *gca* effects in desirable direction are expected to transmit genes with desirable effects to their progeny. Amongst testers, T-397, had desirable significant *gca* effects for days to 50% flowering (-0.43), plant height (-2.58) and harvest index (0.44). Similarly, Shikha was good general combiner only for biological yield/plant (0.24). Among the lines, Neelam, Sheela, NDL-97-7 and Garima were good general combiners for seed yield/plant. Sweta, Shekhar, Sheela and Shubhra had significant *gca* effects for capsules/plant. The lines Garima and Neelam were good general combiners for seeds/capsule.

A comparison of parents on the basis of *gca* effects and mean performance revealed that Neelam was superior to remaining parents in the secondary branches/plant, seeds/ capsule, 1000-seed weight, biological yield/plant due to its high *gca* and high mean performance, however, this concept was not true for other entries. Rashmi gave higher *per se* performance for seed yield but had poor combining ability. The variety NDL-97-7 showed high *gca* and mean performance for seed yield and harvest index.

Six crosses for biological yield and harvest index; five for seed yield and capsules/plant; four for 1000-seed weight; three for seeds/capsule, secondary branches/plant, plant height and days to maturity and two for days to 50% flowering revealed significant desirable *sca* effects for these traits. Among the crosses NDL-97-7 x T-397 was the best specific combination for seed yield/plant and capsules/plant having high x average and low x low *gca* parent, respectively (Table 2). The cross Shekhar x Shikha and Garima x Shikha showed highest *sca* for seeds/capsule and 1000-seed weight, respectively.

Table 2 Best specific cross combinations for 10 characters in linseed

Character	Best cross	*sca* effect	Mean value	*gca* status of the parents	
				P_1	P_2
Days to 50% flowering	Shekhar x Shikha	-0.78**	89.31	H	L
Days to maturity	Shekhar x Shikha	-5.11**	119.32	H	L
Plant height	Neelam x Shikha	-5.05**	82.34	H	H
Secondary branches/plant	Shubhra x Shikha	1.10**	10.59	L	L
Capsules/plant	NDL-97-7 x T-397	8.82**	36.00	L	L
Seeds/capsule	Shekhar x Shikha	0.63**	6.95	L	L
Seed yield/plant	NDL-97-7 x T-397	0.46**	2.77	H	A
1000-seed weight	Garima x Shikha	0.53**	7.15	L	L
Biological yield/plant	NDL-8 x Shikha	0.92**	17.69	L	H
Harvest index	NDL-97-7 x T-397	2.71**	17.55	H	H

** = Significant at P=0.01 level H = High; A = Average; L = Low

Therefore, it is obvious that additive and non-additive types of gene action were involved in controlling seed yield and other traits. Thus, to improve seed yield, biparental mating and recurrent selection is advocated.

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J. Oilseeds Res., **23**(2) : **308-310 (2006)**

Short communication

Genotype x environment interaction for seed and fibre yield in dual purpose flax, *Linum usitatissimum* L. cultivars

S. Bhateria, Anju Pathania, Neelam Sharma and D. Badiyala

Department of Plant Breeding and Genetics, CSK Himachal Pradesh Krishi **Vidyapeeth, Palampur-176 062, HP**

(Received: June, 2001; Revised: February, 2006; Accepted: June, 2006)

Flax (*Linum usitatissimum* L.) is an important ecofriendly industrial oilseed crop of India. In recent years, due to its dwindling area, efforts are afoot to exploit it as a value added crop i.e. seed for oil production and fibre for textile and other industrial as well as domestic uses. Oilseeds in general and flax in particular, are grown on marginal lands without assured irrigation and plant protection measures. However, the environmental conditions of North-Western Himalayan regions are suitable for the production of quality flax. In order to stabilize the production and productivity of flax it was considered imperative to evaluate the newly developed dual purpose flax genotypes endowed with high degree of adaptability combined with superior productivity levels over a range of North-Western Himalayan ecogeographical conditions for successfully exploiting its inherent potential. This investigation is an endeavour to evaluate the performance of some dual purpose flax genotypes to find out high yielding stable one for the region.

The experimental material comprised of 15 genotypes (11 fixed dual purpose lines, 2 flax lines- Flak-1 and Aoyagi and two dual purpose standard checks- Jeewan and Nagarkot). The material was evaluated in a randomized complete block design with three replications at the experimental farm of CSKHPKV, Palampur situated at 1290 meters above mean sea level, for three consecutive years. Each genotype was grown in 3.5 m x 2.0 m plot with inter- and intra- row spacing of 20 cm and 5 cm, respectively. The recommended package of practices of the region was followed to raise the crop. The observations were recorded on ten randomly taken competitive plants per replication for yield and component traits. Stability analysis was done following Eberhart and Russell model (1966).

The analysis of variance for individual as well as pooled environment showed that the mean sum of squares due to genotypes were significant both for seed and fibre yield and other related characters, indicating thereby the presence of substantial genetic variability in the mean performance of genotypes over environments. Pooled analysis (Table 1) also revealed significant variation among environments and their influence on yield (seed and fibre) and the component characters. Significant mean squares due to genotype x environment interaction are suggestive of differential performance of the genotypes under different environments. Significant mean squares due to environment (linear) indicated that variation among environments is linear. A linear environmental variance would signify unit change in environmental index for each unit change in environmental conditions. However, G x E linear component significant for seed yield/plant, seeds/capsule, capsule/plant and branches/plant was indicative of differential performance of genotypes for these traits under diverse environments but with considerably varying reaction norms i.e. the linear sensitivity of different genotypes is variable. The magnitude of variance due to environment (linear) effect was higher than G x E interaction (linear) for all the traits which depicted that major part of the total variation was a linear function of environment only. Significant pooled deviation suggests that performance of different varieties fluctuated significantly from their respective linear path of response to environments. The predominance of linear component noticed for the characters would help in predicting the performance of the genotypes across environments.

The mean ($\bar{x}$), regression coefficient (bi) and deviation from regression (s^2d) for grain and fibre yield and other related traits are presented in Table 2. In the present investigation the magnitude of regression coefficient (bi) and deviation from regression varied from genotype to genotype. Paroda and Hays (1971) suggested that the regression coefficient could be regarded as a varietal response to environmental fluctuations while deviation around the regression line would be the suitable measure of its stability. The genotypes with non- significant deviation from regression were considered stable. Eight genotypes *viz.*, DPL-1, DPL-6, DPL-8, DPL-12, DPL-13, DPL-14, DPL-17 and Flak -1, were found stable for fibre as well as for seed yield. Stability of genotypes for yield is the consequences of stability for its component traits (Grafius, 1956). So general adaptability for yield might be

Table 1 Pooled analysis of variance (MSS) for different characters in dual purpose flax

Source	df	Yield / plant (g)		Seeds/ capsule	Capsules/ plant	Branches/ plant	Plant height (cm)	Crop duration (days)
		Seed	Fibre					
Genotypes (G)	14	0.012*	0.004*	0.099*	31.865*	1.601*	69.612*	12.567*
Environments (E)	2	55.243*	0.186*	55.552*	1504.060*	28.145*	4784.282*	285.803*
G x E	28	0.015*	0.002*	0.291*	42.924*	1.377*	38.887*	3.037*
E (linear)	1	1.105*	0.373*	105.104*	3008.150*	56.291*	5568.593*	569.367*
G x E (linear)	14	0.006*	0.003*	0.129*	8.078*	0.963*	55.431*	4.279*
Pooled deviation	15	0.007*	0.001*	0.423*	72.586*	1.673*	20.051*	1.691*
Pooled error	84	0.001	0.0001	0.033	0.833	0.046	1.740	0.244

* Significant at P = 0.05

Table 2 Estimates of different stability parameters for seed and fibre yield and related attributes in dual purpose flax

Genotype	Yield/plant (g)						Seeds/capsule			Branches/plant			Plant height (cm)			Crop duration (days)		
	Seed			Fibre														
	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di
DPL-1	1.95	0.92	-0.74	0.68	0.68	0.0	6.63	0.88	0.71*	7.52	1.48	1.3*	66.38	1.14	-0.74	182	0.82	0.14
DPL-6	1.90	0.85	-0.08	0.62	0.96	0.0	6.47	1.15	-0.02	6.78	0.48	1.8*	66.90	0.99	-0.08	180*	0.74	5.70*
DPL-7	1.76	0.66	40.2*	0.48	0.71	0.0	6.56	0.95	-0.03	6.87	1.51	0.08	61.52	0.62	40.2*	197	1.24	-0.23
DPL-8	1.68	0.94	1.05	0.44	0.82	0.0	6.39	1.24	0.11	6.47	1.44	0.55	68.03	0.83	-1.05	189	1.21	-0.12
DPL-9	1.90	1.36	11.3*	1.64*	1.62*	0.0	6.82	0.78	-0.01	5.92	0.55	0.31	70.03	0.98	11.3*	182	0.93	2.93*
DPL-12	2.98*	1.93*	-0.75	1.26*	0.34	0.0	7.17*	0.38*	0.06	7.14	0.57	4.3*	81.6*	0.95	-0.75	179*	0.45*	0.12
DPL-13	1.11	1.10	-1.38	0.56	1.40*	0.0	6.30	0.99	0.00	6.84	1.61	5.9*	67.03	0.77	-1.38	177*	1.30	-0.10
DPL-14	1.15	1.23	0.54	0.68	1.09	0.0	6.30	0.99	0.00	8.12*	1.01	1.6*	64.50	0.82	0.54	183	0.33*	-0.21
DPL-16	1.90	0.53	3.95	0.62	0.52	0.0	6.38	0.95	0.63*	7.03	1.24	0.41	62.62	0.68	30.9*	179*	1.45*	11.7*
DPL-17	3.13*	1.98*	1.06	1.48*	0.41	0.0	7.26*	0.42*	0.12	7.76*	1.49	0.12	89.0*	0.57	2.00	176*	0.41*	0.46
DPL-19	2.90*	0.63	4.18	0.96	1.07	0.0	7.02	4.83*	-0.03	7.41	1.34	2.2*	78.5*	1.32	64.2*	183	0.93	-0.20
Flake-1	1.74	0.83	1.17	1.30*	0.83	0.0	6.27	0.97	0.67*	5.46	0.16*	0.41	77.3*	0.96	1.17	184	1.59*	1.29
AOYAGI	1.56	1.18	21.8*	1.64*	1.05	0.0	6.18	1.09	0.56*	6.23	0.12*	0.40	75.9*	1.60*	21.8*	185	1.02	0.45
Jeewan	1.83	0.51	59.1*	0.92	0.78	0.0	6.60	0.84	0.69*	6.09	0.86	0.10	70.19	1.25	59.1*	183	0.49*	-0.06
Nagarkot	1.27	0.69	59.4*	1.62*	1.68*	0.0	6.89	1.11	2.43*	7.33	1.42	4.7*	81.5*	1.81*	59.4*	183	1.06	-0.13
Population mean	2.3			0.93			6.62			6.86			71.99			182		

* Significant at P = 0.05

attributed to their stability in other component traits. Only DPL-12 and DPL-17 gave above average seed and fibre yield, seeds per capsule, plant height and had desirable minimum crop duration (179 and 176 days). These two genotypes however, were adaptable for better environment for seed yield (bi>1), whereas for fibre yield, seeds per capsule, plant height and crop duration, these were adaptable for poor environment (bi<1).

Both the flax varieties (Flak-1 and Aoyagi), exhibited wider adaptability for fibre yield. Many earlier workers like Singh and Srivastava (1989) had reported stability for technical height and straw yield, Rai *et al.* (1989) had observed one stable variety for all the characters, while Mahto *et al.* (1994) had observed variable response for various traits.

In summation, though none of the genotype was stable for all the characters yet, two of these genotypes *viz.*, DPL-12 and DPL-17 were observed to be promising and stable for seed and fibre yield and other important traits. Hence, these can be utilized for harnessing the dual purpose character. On the other hand, Flak-1 and Aoyagi can only be exploited as fibre types in the mid-hill regions of Himachal Pradesh.

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J. Oilseeds Res., **23**(2) : 311-313 (2006)

Short communication

Self-incompatibility and seed set under different kinds of bagging methods for selfing in niger, *Guizotia abyssinica* Cass

H.S. Patil and S.S. Duhoon

All India Coordinated Research Project on Niger, Zonal Agricultural Research Station, Igatpuri-422 403, MS

(Received: May, 2005; Revised: September, 2005; Accepted: October, 2005)

India stands first in the production of niger in the world. From a mere 9324 tones valued at Rs. 21.36 crores, exports have gone up to 22,200 tones valued at Rs. 47.85 crores in 2001-2002. World trade in niger is about 50,000 tonnes and India is a major supplier to the world market. Besides, mainly used as bird feed, it is also a major ingredient in cattle feed mixture. It is cultivated as a minor oilseed crop in Madhya Pradesh, Orissa, Maharashtra, Bihar, Jharkhand, Karnataka and Andhra Pradesh and is extensively grown under rainfed conditions by marginal and submarginal tribal farmers. Though it has low productivity, production of seed depends on successful flowering, fruiting and seed setting. Thus, it becomes essential to gather information on the production of self seeds in considerable quantity, so that inbred can be developed for evolving new composite / hybrid. Therefore, the present study was conducted to know the self compatibility and the extent of seed sett in different types of bagging.

The present investigation was carried out at Zonal Agricultural Research station, Igatpuri during rabi season of 2001- 2002. Fifty genotypes of niger with three check varieties were grown in Randomized Block Design with three replications with a spacing of 30 x 10 cm. Ten buds from randomly selected 10 plants of each genotype were bagged with muslin cloth, oil paper, craft paper and newspaper bags just before the flowering. Number of seed set/capitula were counted at maturity and seed set under different bagging are reported and discussed here and presence of self compatibility was assessed.

It is revealed from the Table 1, that the bagging of individual bud has an adverse effect on seed setting which ranged from 1 seeds to 4 seeds/capitula over different methods. However, seed set in muslin cloth bagging was in the range of 1 to 3 seeds and it was followed in oil paper bagging 1 to 4, in craft paper bagging 1 to 5 and in newspaper bagging 1 to 4. Previous investigations of Nemomissa *et al.* (1999) have shown that flowering in confined space reduces chance of pollination and thus interferes considerably with number of the seed set.
Different genotypes behaved differently for seed setting in different types of bagging. The highest and lowest seed setting in different bagging methods observed is as furnished below:

	Muscline cloth	Oil paper	Craft paper	Newspaper
Highest seed set	GA-10 3 seeds	JN-120 and 134 4 seeds	JN-106 4 seeds	JN-130 4 seeds
Lowest seed set	IGP-76 0.79 seeds	UN-218 0.40 seeds	RCR-234 0.26 seeds	RCR-234 0.40 seeds

On the basis of mean performance over all these four methods of bagging, five genotypes have shown the seed set more than three seeds and eighteen genotypes have shown seed set more than two seeds. JN-134 (4 seeds) was the highest seed setter and it was followed by JN-120 (4 seeds), JN-122 (4 seeds) and RCR-234 (1 seeds) was lowest seed setter.

Under open pollination condition CHH-6 (46 seeds) was the highest seed setter followed by CHH-63 (40 seeds), CHH-7 (40 seeds), CHH-32 with 40 seeds each and CHH-26 (37 seeds). The genotype UN - 218 (14 seeds) was the lowest seed setter.

The individual genotype behaved differently for seed setting in different types of bagging. The seed setting under different methods as well as under open pollination clearly indicates the presence of self incompatibility. However, the genotypes *viz*, JN-134 , JN-120, JN-122 have shown the self compatibility under different bagging methods.

Sujatha (1993) observed that the pistils at all stages of development failed to promote seed set after self pollination. This indicates that the niger population is self incompatible one and absence of preanthesis pollination is there. Similarly, in the present study, the average seed set was in the range of 1 seeds to 4 seeds/capitula. On an average seed setting over all four selfing methods, 18 genotypes have seed setting of more than two seeds and five genotypes have more than three seeds/capitula.

Table 1 Number of seed set/capitula in different selfing methods in niger

Genotype	Number of seeds/capitula					
		Pollination under different selfing methods				
	Open pollination	Muscline cloth bag	Oil paper bag	Craft paper bag	Newspaper bag	Average
JN-99	27	2	3	5	3	3
JN-106	27	2	3	5	3	3
JN-120	26	3	4	4	3	4
JN-121	25	3	4	4	2	3
JN-122	27	3	4	4	3	4
JN-127	26	3	3	3	2	3
JN-130	26	3	4	4	4	4
JN-134	26	3	4	4	3	4
JN-135	25	3	4	4	3	3
JN-145	26	3	4	4	3	4
NRS-96-1	30	3	3	3	3	3
NRS-96-3	30	3	3	3	3	3
NR-76-74	29	2	2	2	2	2
NR-373-3	20	2	3	2	2	2
CHH-6	46	2	3	3	2	2
CHH-7	39	2	3	3	2	2
CHH-26	37	2	3	3	2	2
CHH-32	39	2	3	3	2	2
CHH-63	40	2	3	3	3	3
RCR-23	17	2	3	4	3	3
RCR-234	17	1	1	1	1	1
RCR-290	25	1	1	1	1	1
RCR-320	25	1	1	1	1	1
RCR-5-74	*20*	*2*	*3*	*3*	*3*	*3*
GA-1	25	3	2	3	2	2
GA-2	20	3	2	3	3	2
GA-5	21	3	2	2	2	2
GA-8	20	3	2	2	2	2
GA-22	16	3	2	2	2	2
GA-25	21	3	2	3	3	2
GA-27	25	3	2	2	2	2
GA-96	19	2	2	3	2	2
BNS-1	27	2	2	3	2	2
BNS-4	18	1	2	3	2	2
BNS-6	29	1	2	3	3	2
BNS-7	25	1	2	4	2	2
BNS-8	22	2	2	1	2	2
BNS-9	26	1	2	2	2	2
BNC-2	26	1	2	1	1	2
BNC-20	25	1	2	1	2	2
PNS-8	22	1	2	3	2	2
PNS-21	21	2	3	3	2	2
PNS-25	20	2	3	3	3	2
PNS-921	19	1	3	3	3	2
UN-4	20	1	1	2	2	2
UN-218	14	1	1	2	1	1
UNS-9	22	1	2	1	2	2
87-14	21	2	2	2	2	2
34-14	16	2	2	1	2	2
41-52	30	2	2	2	2	2
No. 71 ©	26	3	4	4	3	3
G A – 10 ©	24	3	2	3	2	2
I G P – 76 ©	32	1	2	1	1	1
Average	25	2	2	3	2	2

This supports the view of Sujatha (1993) that the niger population is self incompatible. However, the maximum average seed set of 2 and 3 seeds/capitula in oil and craft paper bagging respectively indicates the existence of self compatible types also in natural population. To achieve this goal, rigorous screening of large number of genotypes is needed. Sinha *et al.* (1993 and 1994) also opined the same.

Oil paper and craft paper bagging on an average were superior to other bagging methods for seed set. Significant reduction in seed setting was observed in muslin cloth and news paper bagging. This reduction may be attributed to high humidity, low intensity of solar radiation, and poor pollen movement inside the bag. Similar observations have been reported by Mohanthy (1965), Sinha *et al.* (1993 and 1994), Kumar *et al.* (1998) and Patil (2003) in niger, and Shivaraju *et al.* (1987) in sunflower.

Thus, it can be concluded that the seed set was more under oil paper and craft paper bagging and less in muslin cloth and news paper bagging. The genotypes *JN-120 and JN-134 (4 seeds) were the highest seed setter* under oil paper bagging; the genotype JN-106 (5 seeds) under craft paper bagging and JN-130 (4 seeds) under newspaper bagging of selfing methods. This may be due to air circulation, relative humidity and temperature to facilitate pollination under selfing. The results indicate the possibility of developing inbreds to facilitate hybrid development in niger.

Indian Council of Agricultural Research, New Delhi is gratefully acknowledged for financial support through Cess Fund Adhoc Research Project and Associate Director of Research, ZARS, Igatpuri for providing the necessary facilities for experimentation.

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J. Oilseeds Res., **23**(2) : **314-317 (2006)**

Short communication

Chemically induced male sterility in niger, *Guizotia abyssinica* (L.) Cass

S. Gangaprasad, R.V. Sreedhar, R.L. Ravikumar and P.M. Salimath

Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad-560 065, Karnataka

(Received: February, 2005; Revised: December, 2005; Accepted: December, 2005)

Studies on induction of male sterility in crop plants using gametocides are of considerable economic importance since male sterility facilitates production of F_1 hybrid. Male sterility also facilitates population improvement. Development of high yielding varieties and hybrids in niger need no emphasis, since it contributes for supply of vegetable oils. Controlled crossing in niger needs artificial induction of male sterility due to absence of natural sources of male sterile lines. In view of the small flower size, manual emasculation is very tedious and practically not feasible in crops like niger. The other viable alternative is the use of chemicals as male gametocides. In order to address the need, present investigation was undertaken to induce male sterility through chemicals. Such studies are very important in a crop like niger, which is essentially cross pollinated with enormous scope for exploitation of hybrid vigour.

For induction of male sterility using various chemicals, seeds of N-71 were sown in rows of 3 m length with all recommended agronomic practices. The chemical treatments were given as shown in Table 1. Each treatment was given to four randomly selected plants and chemicals were sprayed on entire plant surface using a hand sprayer. Pollen sterility at anthesis was recorded using pollen germination medium of sunflower, which has a composition of 1.5 ml sucrose, 2.23 ml PEG, 0.1 ml boric acid, 0.1 ml potassium nitrate, 0.05 ml magnesium sulphate and 0.066 ml calcium nitrate per 5 ml. Pollen grains were collected separately from primary and secondary capitula from all treated and control plants. Un-germinated and germinated pollen grains were counted and expressed in percentage to know sterility of variously treated plants.

The results of present study are presented in Table 2. GA_3 proved to be the most successful chemical to induce maximum male sterility compared to other chemicals used. Spraying GA_3 at a concentration of 150 ppm at bud initiation stage for three successive days could induce male sterility as high as 80.21% in the primary buds. When the same concentration was used at the same stage for one day, it showed 69.13% pollen sterility in the primary buds. The other treatment that could give good amount of male sterile flowers was from 150 ppm GA_3 applied during star bud stage for three days and gave 66.80% sterile pollen. Induction of high magnitude of male sterility in case of sunflower by use of GA_3 has been reported by Schuster (1969), Seetharam and Kusumakumari (1974; 1975), Garcia Torres *et al.* (1979) and in niger by Veerakumar (2002). Concentration of GA_3 seems to have a major role in induction of pollen sterility. Use of 150 ppm GA_3 was found to be more effective in inducing male sterility. These observations are in accord with those observed by Veerakumar (2002) in niger. However, results of Seetharam and Kusumakumari (1974; 1975) and Garcia Torres *et al.* (1979) have shown that a lower concentration of less than 150 ppm induced maximum pollen sterility in sunflower. Regarding stage of application, spraying at bud initiation stage proves to be better. This is also supported by works of Schuster (1969) and Seetharam and Kusumakumari (1974; 1975). Adverse morphological changes were also observed like excessive elongation of terminal parts of shoot. Reduction in inflorescence size of sunflower was observed by Vittalraya Kini (1981).

Induction of pollen sterility by treating with 2, 4-D proved to be a failure at both the concentrations selected for the present study due to severe deformities in plant shoot and the inflorescence. Abnormal curling of shoot tip and young branches with newly formed leaves which resulted in death of the whole plant in later stages suggest that use of 2,4-D at concentrations of 50 and 100 ppm is unwarranted as a gametocide. Similar observations were made by Sreenivasa (2001) in his study on brinjal. Janakiraman and Natarajan (1999) could induce pollen sterility of 46.7% using 50 ppm 2,4-D and lower levels of pollen sterilities using lower concentrations but at last all treatments gave no seed and fruit in case of brinjal. Salgare (1999) who worked on *Phaseolus mungo* for induction of male sterility using 2, 4-D also concluded that concentration ranging from 200 to 5000 g/ml killed all plants. From the present study it can be concluded that 2,4-D is not a suitable chemical to use as a gametocide in niger.

Table 1 Various treatments for chemical induction of male sterility

Chemical	Concentration	Stage of application	No. of sprays	Treatment number
GA_3	100 ppm	Bud initiation	1	T_1
			3*	T_2
		Star bud	1	T_3
			3*	T_4
	150 ppm	Bud initiation	1	T_5
			3*	T_6
		Star bud	1	T_7
			3*	T_8
2,4-D	50 ppm	Bud initiation	1	T_9
			3*	T_{10}
		Star bud	1	T_{11}
			3*	T_{12}
	100 ppm	Bud initiation	1	T_{13}
			3*	T_{14}
		Star bud	1	T_{15}
			3*	T_{16}
Surf excel (W/V)	1%	Bud initiation	1	T_{17}
			3*	T_{18}
		Star bud	1	T_{19}
			3*	T_{20}
	2%	Bud initiation	1	T_{21}
			3*	T_{22}
		Star bud	1	T_{23}
			3*	T_{24}

* One spray/day for three successive days.

Table 2 **Pollen sterility (%) at different chemical concentrations and growth stages**

Chemical	Concentration	Stage of application	No. of sprays	Treatment No.	Pollen sterility (%)	
					Primary bud	Secondary bud
Control				T_0	17.84	35.70
GA_3	100 ppm	Bud initiation	1	T_1	53.12	41.21
			3	T_2	64.67	46.90
		Star bud	1	T_3	49.81	51.22
			3	T_4	54.60	58.27
	150 ppm	Bud initiation	1	T_5	69.13	53.12
			3	T_6	80.21	56.70
		Star bud	1	T_7	53.30	55.32
			3	T_8	66.80	59.32
2,4-D	50 ppm	Bud initiation	1	T_9	*	*
			3	T_{10}	*	*
		Star bud	1	T_{11}	*	*
			3	T_{12}	*	*
	100 ppm	Bud initiation	1	T_{13}	*	*
			3	T_{14}	*	*
		Star bud	1	T_{15}	*	*
			3	T_{16}	*	*
Surf excel (W/V)	1%	Bud initiation	1	T_{17}	58.20	41.20
			3	T_{18}	*	*
		Star bud	1	T_{19}	42.91	46.87
			3	T_{20}	*	*
	2%	Bud initiation	1	T_{21}	*	*
			3	T_{22}	*	*
		Star bud	1	T_{23}	*	*
			3	T_{24}	*	*

* Plant mortality

A single spray of surf excel resulted in inducing reasonable level of pollen sterility at a concentration of 1%. However, spraying it for three days or use of 2% solution proved to affect adversely the plant development. The treatments led to leaf scorching, drying of shoot buds, irregular development of inflorescence and later inflorescence drying. It could be due to the presence of additives in detergents like anti-deposition agents, bleaching agents, organic sequestering agents and enzymes along with sodium carbonate and sodium borate, which can be harmful to the plant. But studies by Singh (1999) in rice and Chauhan and Vandana Singh (2002) in *Brassica juncea* (L.) reported that detergents were able to induce very high pollen sterility at concentrations as high as 3 to 6%. Use of the detergent at lower concentration might be successful for induction of pollen sterility without affecting the plant. However the success of spraying the chemicals to exploit for inducing male sterility depends on a detailed study to identify a suitable chemical, dosage, and mode of application and stage of application. The chosen chemical and its concentration used should be able to induce male sterility in all the inflorescences of a plant before it can be effectively used to exploit heterosis and population improvement in Niger. There is also a need to conduct detailed studies to identify the ideal chemical, its effective concentration and correct stage of single and multiple applications in order to induce pollen sterility in all the capitula.

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J. Oilseeds Res., **23**(2) : **318-319** (2006)

Short communication

Evaluation of seed characteristics in *Jatropha curcas* L.

Y. Ravindrababu, M.V. Patel, V.C. Joshi, K.J Desai and B.M. Patel

AICRP on Under Utilized Crops, RRS, S.D. Agricultural University, Sardarkrushinagar-385 506, Gujarat

(Received: July, 2005; Revised: December, 2005; Accepted: December, 2005)

Jatropha curcas L. locally known as Ratanjyot has gained importance in recent years by virtue of the oil present in its seed. It belongs to the family *Euphorbiaceae* and is closely related to castor (Sathaiah and Reddy, 1985; Reddy *et al.*, 1987). The transesterified oil can be used as biodiesel. The seed oil in *Jatropha* is used in soap manufacturing, lubricants, illumination, candle manufacturing and also as a hair oil. The oil percent in seed varies from 30-35 % depending upon availability of soil moisture and other environmental factors (Nagabhushanam and Raghavaiah, 2005). Seed is the ultimate propagule of a plant produced through the union of the male and female gametes. Seed is an important input in agriculture. Seed size is an important agronomic trait and major oil yield component in *Jatropha*. Large seeds are preferred for easy crushing and oil extraction. In tree breeding quick improvement can be achieved by identifying seed source and plus tree. The plus tree selection is scored on the basis of high seed yield coupled with oil content and seed size. Therefore, the present study was attempted to collect seed through explorations from different sources (districts) for identification of high oil yielding genotypes in *Jatropha* and their utilization in improvement of *Jatropha*.

Seeds were collected from 36 plus trees with yield potential of more than two kilograms seed per tree. The districts were covered from semi-arid/ arid region of Banaskantha district to high rainfall zone of Dahod and Panchmahal of Gujarat state. The collected seed from plus trees were characterized for seed attributes *viz.*, seed length, seed breadth, seed thickness, test weight and oil per cent. The observations for seed length, seed breadth and seed thickness in mm were measured with the help of digital vernier calipers. The test weight was measured by counting hundred seeds randomly from the seed samples and weighed in grams, while oil content was estimated by using NMR techniques (Nuclear Magnetic Resonance Technique) from collected seed samples. The mean values were subjected to standard procedure of statistical analysis (Chandel, 1995).

The data on seed length, seed breadth, seed thickness, test weight and oil content are presented in Table 1. The data revealed that the mean value for length of seed was 16.22 + 0.11. Maximum seed length was observed in seed source SKNJ-509 (17.56 mm) while lowest value was recorded in SKNJ-510 (15.30 mm). The mean values for seed breadth of seed were 10.77 ± 0.05. Maximum breadth was observed in seed source SKNJ-512 (11.40 mm) where as lowest value was recorded in SKNJ-501 (10.19 mm). The population mean of 59.86 ± 1.11 was recorded for test weight with range of 46.44 ± 70.51g. The highest test weight was recorded in SKNJ-527 (70.51g). The mean value for oil content was 36.55 ± 0.56. The maximum oil content was observed in SKNJ-521 (43.46%) followed by SKNJ-536 (43.34%). The lowest oil was recorded for SKNJ- 508 i.e., 28.71%. The genotype SKNJ-526 and SKNJ-532 have had oil content coupled with high test weight.

From the fore going discussions, it is evident that for getting maximum test weight and oil recovery the genotypes SKNJ- 532, SKNJ- 521 and SKNJ-527 found promising. SKNJ-518 exhibited highest seed length and seed breadth in combination with good oil content and test weight. Hence, these genotypes may be included in breeding programme for further improvement in this crop.

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Table 1 Seed characteristics in *Jatropha curcas* genotypes

Genotype	Source	Length of Seed (mm)	Breadth of seed (mm)	Seed Thickness (mm)	Test weight (g)	Oil content (%)
SKNJ-501	Ambaji	16.1	10.2	8.3	52.5	36.2
SKNJ-502	Ambaji	16.2	10.5	8.2	64.5	34.5
SKNJ-503	Ambaji	16.6	10.9	8.3	61.1	36.5
SKNJ-504	Ambaji	16.7	10.8	8.4	46.4	33.5
SKNJ-505	Ambaji	15.5	10.8	8.5	58.2	40.0
SKNJ-506	Ambaji	15.7	10.6	8.0	55.1	32.8
SKNJ-507	Ambaji	16.2	10.5	8.0	64.3	37.2
SKNJ-508	Ambaji	15.5	10.2	8.5	47.2	28.8
SKNJ-509	Ambaji	17.6	11.3	8.9	67.9	36.2
SKNJ-510	Ambaji	15.3	10.4	7.8	62.1	38.3
SKNJ-511	Simalpad	15.9	10.7	9.0	62.4	36.2
SKNJ-512	Ambaji	15.9	11.4	8.3	65.4	34.7
SKNJ-513	Ambaji	16.9	11.0	8.5	69.0	35.8
SKNJ-514	Viramveri	16.6	10.8	8.0	59.1	39.0
SKNJ-515	Ambaji	17.1	10.9	9.4	67.5	35.7
SKNJ-516	Ambaji	16.8	10.8	8.8	61.6	33.8
SKNJ-517	Simalpad	16.5	10.8	8.5	62.9	36.1
SKNJ-518	Karmad	17.4	11.3	8.8	67.2	40.4
SKNJ-519	Pania	16.0	11.0	8.1	49.3	31.7
SKNJ-520	Pratappura	15.8	10.3	8.2	57.8	39.9
SKNJ-521	Pania	16.4	11.3	8.4	61.9	43.5
SKNJ-522	SKNagar	16.6	10.8	8.4	49.1	32.2
SKNJ-523	Hyderabad	16.8	10.9	8.0	57.2	33.3
SKNJ-524	Limkheda	16.5	10.9	8.4	58.2	35.0
SKNJ-525	Ambaji	15.4	10.5	7.6	54.3	38.4
SKNJ-526	Chaparvad	17.1	10.7	8.0	68.0	40.0
SKNJ-527	Kaliarai	15.7	10.6	7.9	70.5	36.7
SKNJ-528	Randhikpur	15.6	10.5	8.2	58.3	39.3
SKNJ-529	Juda	15.6	10.9	8.1	64.6	39.3
SKNJ-530	Kangaro	15.6	10.6	8.4	50.6	34.0
SKNJ-531	Kangaro	16.6	10.9	8.4	63.9	36.1
SKNJ-532	Kangaro	17.3	11.0	8.4	68.6	39.8
SKNJ-533	Ambaji	15.1	10.3	8.9	50.4	31.8
SKNJ-534	Thaparvat	15.7	11.2	7.8	60.1	41.0
SKNJ-535	Bhoila	15.7	10.3	7.4	55.3	34.8
SKNJ-536	Randhikpur	16.1	11.1	7.3	62.4	43.3
Mean		16.22	10.77	8.27	59.86	36.55
SD		0.643	0.321	0.434	6.660	3.342
Variance		0.413	0.103	0.189	44.359	11.166
SEm±		0.107	0.053	0.072	1.110	0.557
CV (%)		3.961	2.98	5.250	11.126	9.144

J. Oilseeds Res., 23(2) : 320-324 (2006)

Short communication

Screening of different germplasm of groundnut, *Arachis hypogaea* L. in saline environment

I.K. Girdhar and P.K. Bhalodia

National Research Centre for Groundnut, P.Box No. 5, Junagadh-362 001, Gujarat

(Received: August, 2005; Revised: February, 2006; Accepted: June, 2006)

About 51.2% of total irrigated area in India is covered by well irrigation. Hence, groundwater is an important source of irrigation next to surface water irrigation. Majority of the groundwater in the arid, semi arid and coastal region is of poor quality and availability of good quality water for irrigation is a limiting factor. Such problem is more wide spread in Saurashtra region of Gujarat and farmers have no option but to use such poor quality saline ground waters for irrigating crops like groundnut under low rainfall. Productivity of groundnut in such problem area is seriously affected. Water generally classified as unsuitable for irrigation, in fact, is used successfully to grow crops. The development of crops with increased salt tolerance will further facilitate the use of saline water for crop production. Hence it is useful to identify salt tolerant germplasm of groundnut in order to utilize saline water.

Sand culture experiment was conducted in the controlled laboratory conditions in *kharif*, 2004 at NRCG, Junagadh, with the objective to screen the different germplasm of groundnut in the saline environment. Forty eight numbers of genotypes of groundnut belonging to Spanish group were taken with four salinity levels [0.5 (control), 4, 8 and 12 dS/m] of the irrigation water in three replications. Four kg of sand was filled in each polythene bag. In total there were 576 polythene bags (pots) used for this investigation. These bags were perforated in order to provide free drainage. Five numbers of seeds were sown in each pot. Observation on germination, plant height and dry matter yield were recorded. Daily irrigation with saline water was given based on the evaporative demand. Saline irrigation water was prepared using commercial salt of sodium chloride. Crop was harvested after 20 days of sowing.

Germination of groundnut genotypes decreased significantly from 91 to 24 percent with an increase in the irrigation water salinity from 0.5 to 12 dS/m (Table 1). Though, the germination at 4 dS/m salinity was significantly lower over the control but the percent decrease at this salinity was low (12%). Almost similar decrease in plant height and dry matter yield was also noticed at 4 dS/m salinity. The percent reduction of these growth parameters at 8 and 12 dS/m salinity was quite high in comparison to control and such saline waters are not safe to use for irrigating groundnut crop. Data on periodic germination under varying salinity (Table 2) showed that high salinity delayed the germination by 4-5 days which may further affect the yield. In a given saline environment, the genotype namely NRCG 5096, 10405, 4468 and 10389 showed the highest germination ranging from 80 to 85 % whereas NRCG 10492, 10051, 10485 and 10537 indicate the poor germination ranging from 45 to 55 %.

Threshold salinity for different genotypes under study were determined in order to study their specific tolerance. It was found that the following germplasm namely NRCG 249, 4171, 5096, 7466, 10326, 10368, 10379 and 10051 are most tolerant to salinity. The threshold salinity of above said genotypes are ranging between 3 to 5 dS/m. This indicates that irrigation water of this salinity would have no restriction on use. NRCG 10257, 10309, 10637, 10491 and 10388 are sensitive to salt tolerance because their value of threshold salinity is <1 dS/m (Table 3). Tolerance of germplasm to different salinity at 50% germination are given in Table 4, showed that the genotypes survived at high salinity of 10-15 dS/m can be used as guidelines for further specific and advanced field study by the plant breeder, cytogenetist, biotechnologist and soil scientist to enhance the salinity tolerance and groundnut production.

Actual observations recorded for germination, plant height and drymatter yield for each germplasm at different salinity levels were used for regression analysis. Based on these 48 regression equations and their R^2 value for the said plant characters, the percent reduction in germination, plant height and dry matter yield over control were calculated and the data on most tolerant and sensitive genotypes are illustrated in Fig. 1 and 2. The data is best fitted in the different regression equations developed for varying plant growth characters of groundnut versus salinity relationship and having a R^2 value ranging from 0.8 to 0.9 in majority of the genotypes. Fig. 1 indicates that 50 % germination was observed at water salinity of 6.3 dS/m in sensitive genotype (NRCG 10257) where as the same germination was noticed at salinity 12.5 dS/m in tolerant genotype (NRCG 5096). The

effect of increasing salinity of irrigation water on relative decrement of plant height and dry matter yield of sensitive and tolerant genotypes of groundnut is depicted in Fig. 2 and showing 50% reduction in plant height and dry matter yield at 8 to 9 dS/m salinity in sensitive genotype (NRCG 10356) and similar reduction was observed at 11 to 12 dS/m salinity in tolerant genotype (NRCG 10307). The tentative selections of these sensitive and tolerant genotypes were done by seeing the relative performance of different genotypes of groundnut at varying salinity in relation to the yield in control treatment (0.5 dS/m salinity of water). Earlier Aljibury and Telabany (1982) reported decrease in groundnut seed production with increasing salinity from 2 to 11.3 dS/m and Lauter and Meiri (1990) found that higher levels of NaCl (70 and 105 mM concentration) caused seed damage prior to pod maturity and much lower seed yield. Girdhar (1987 to 1989), Girdhar *et al.*, 1994, 2004 and Girdhar *et al.*, 2005 reported the tolerance of different crops to soil and water salinity in the fallowing decreasing order.

Sugarbeet > Sunflower > Mustard > Wheat > Pearl millet >Dhaincha > Rice > Guar > Sorghum > Maize > Groundnut.

In conclusion, saline water of 4 dS/m salinity can be used safely in majority of the tested groundnut germplasm. Even 8 dS/m salinity of irrigation water can also be used if 30 % reduction in yield over control (0.5 dS/m) is acceptable. Various threshold salinity limits for tolerant genotypes already discussed in the text can further be used for planning future field studies in this direction. Some of the germplasm which survive at very high salinity but gives poor and unacceptable yield can also be used for further breeding and genetic salt tolerance studies. Further, from the above study it may be clarified that these results should not be translated directly in the field conditions since the effect of climate, texture and type of soils and soil fertility in evaluating tolerance of different germplasm of groundnut has not been taken in to account.

Table 1 Effect of saline water irrigation on germination, plant growth and drymatter yield of groundnut at seedling stage

ECiw* (dS/m)	Germination (%)	Percent decrement in germination	Plant height (cm)	Percent decrease in plant height	Dry matter yield (g/plot)	Percent decrement in dry matter yield
0.5	91	0	26	0	0.96	0
4	80	12	23	12	0.88	9
8	71	22	18	31	0.74	23
12	24	74	7	73	0.22	77
CD(P=0.05)	5		1		0.06	

*ECiw = Electrical conductivity (salinity) of irrigation water

Table 2 Effect of saline water irrigation on periodic germination of groundnut

ECiw(dS/m)	Days after sowing						
	5	6	7	8	9	10	11
0.5	42	75	83	87	90	90	90
4	3	18	49	64	71	76	78
8	2	2	11	41	54	65	69
12	0	0	0	1	11	14	21
CD(P=0.05)	2.6	3.1	4.0	4.2	4.5	4.6	4.8

Table 3 Threshold salinity* of irrigation water for different germplasm of groundnut

ECiw (dS/m) < 1	ECiw (dS/m) 1-3	ECiw (dS/m) 3-5
10257, 10309, 10637, 10491, 10388, 10402, 10492, 10566	3653, 4468, 5507, 5513, 6131, 7145, 7746, 9966, 10344, 10348, 10367, 10478, 10395, 10390, 10485, 10482, 10486, 10537, 10387, 10403, 10389, 10405	249, 4171, 5096, 7466, 10326, 10368, 10377, 10379, 10051, 10484, 10659, 10476

*Threshold salinity is defined as the salinity levels at which germination or yield loss begins. It was estimated from the data of regression analysis.

Table 4 Relative tolerance of different germplasm of groundnut to saline water irrigation at 50 % germination

ECiw (dS/m) 5-10	ECiw (dS/m) 10-15
249, 3653, 4171, 5507, 7145, 9966, 10257, 10309, 10344, 10367, 10368, 10051, 10478, 10395, 10390, 10397, 10485, 10482, 10637, 10491, 10486, 10402, 10492, 10537, 10387, 10661, 10476, 10649, 10662	4468, 5096, 6131, 7466, 7746, 10307, 10348, 10369, 10377, 10388, 10403, 10566, 10484, 10659, 10389, 10405,10379

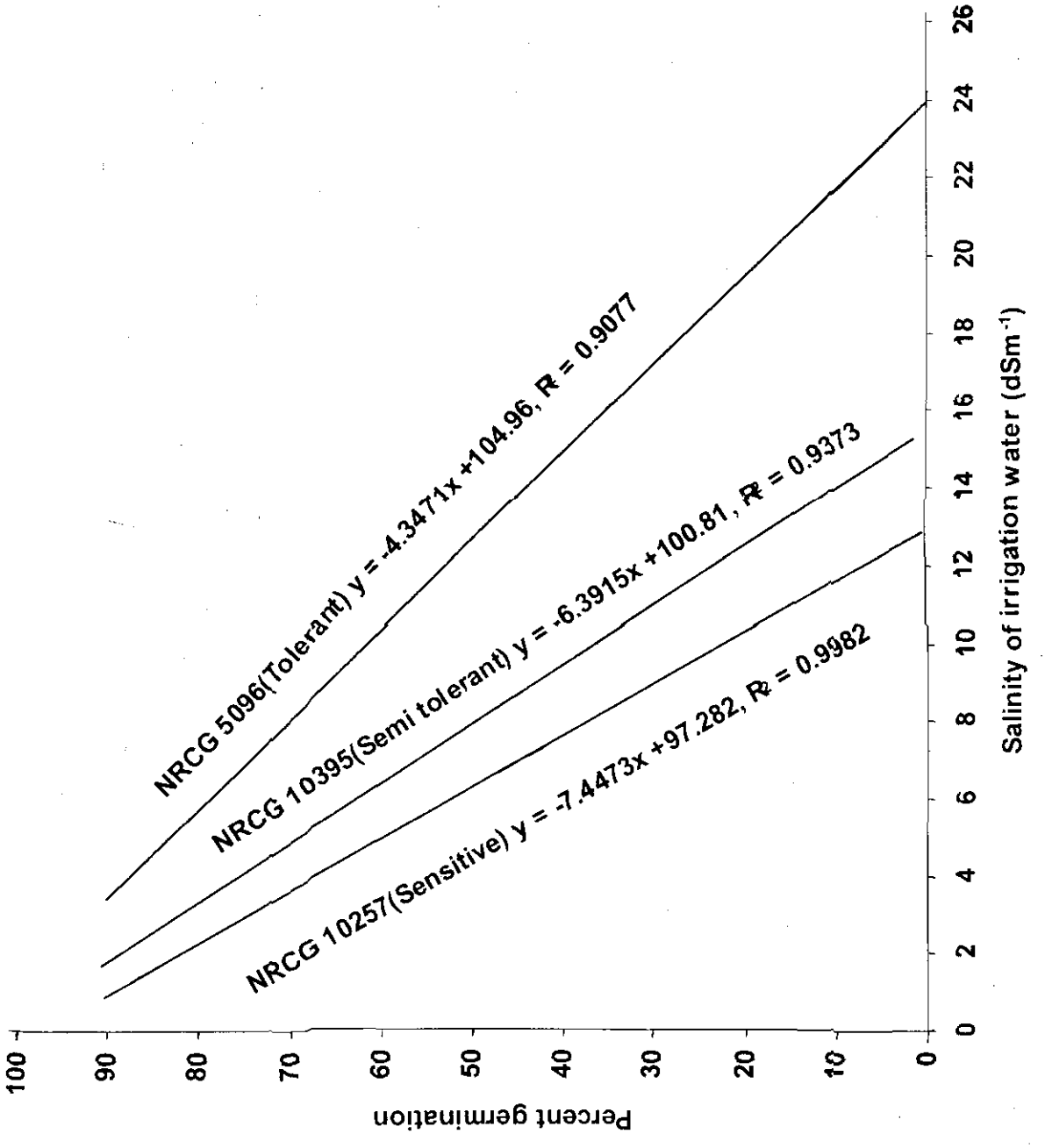

Fig. 1 Effect of salinity of irrigation water on percent reduction over control in germination of groundnut

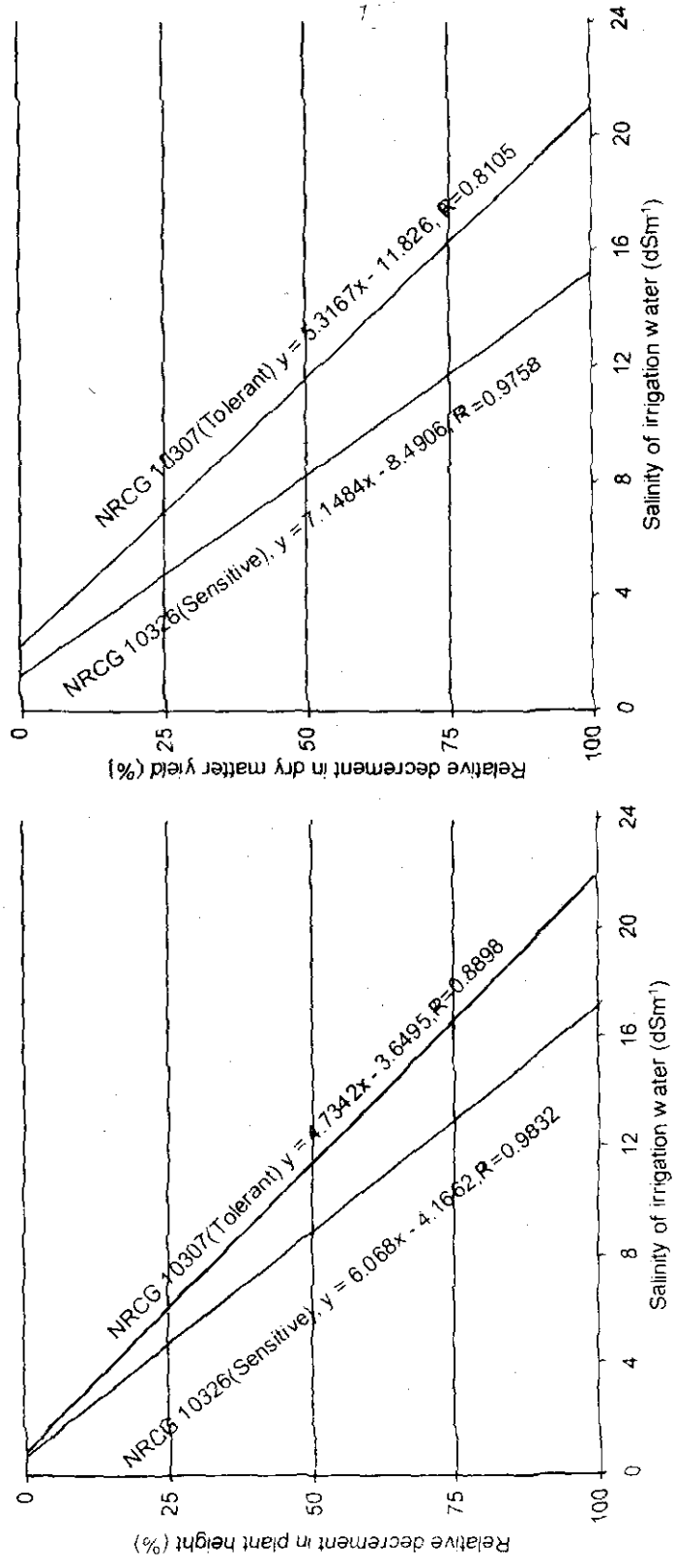

Fig. 2 Effect of saline water irrigation on percent reduction over control in plant height and dry matter yield of groundnut

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J. Oilseeds Res., **23(2) : 325-326 (2006)**

Short communication

Optimization of nitrogen and phosphorus fertilization in soybean, *Glycine max* (L.) Merril under semi arid conditions of Haryana

Sanjeev Chauhan, Parvender Sheoran, Mehar Singh and Mahesh Kumar

Department of Agronomy, CCS Haryana Agricultural University, Hisar-125 004, Haryana

(Received: April, 2005; Revised: August, 2005; Accepted: December, 2005)

Soybean [*Glycine max* (L.) Merril] has established its potential as an industrially vital and viable oilseed crop in many parts of India with highest protein (about 40%) and oil content (about 20%). Among many constraints responsible for not realising its full yielding potentiality, lack of balanced nutrition is one of the most important one. As nitrogen and phosphorus show synergistic effect on each other, the application of phosphorus will enhance the root growth and nitrogen will give a good start to the crop. Looking to the potentials of cultivation of soybean crop in the state, the present investigation was carried out to study the response of soybean to nitrogen and phosphorus fertilization.

A field experiment was conducted at Research Farm of CCS Haryana Agricultural University, Hisar during rainy season, 2000. The soil of experimental field was sandy loam in texture (sand- 76%, silt- 13% and clay-11%), slightly alkaline in reaction (pH 8.2), low in available nitrogen (123 kg N/ha) and organic carbon (0.30%), medium in available phosphorus (15 kg P_2O_5/ha) and high in available potash (387 kg K_2O/ha). The experiment consisted of four levels of nitrogen (0, 20, 40 and 60 kg N/ha) and four levels of phosphorus (0, 40, 60 and 80 P_2O_5 kg/ha). A total of sixteen treatment combinations were laid out in Factorial Randomised Block Design with three replications. Prior to sowing, a common pre-sowing irrigation of 10 cm depth was applied in the field to obtain a uniform crop stand. Soybean variety PK 416 was sown in the third week of July by pora method using 80 kg seed/ha at a row spacing of 40 cm and thinning was done after 15 days of sowing to maintain plant to plant spacing of 10 cm. All other cultural practices were followed as per package of practices for the crop sown. Five randomly selected plants were taken for recording dry matter accumulation, yield attributing characters and ultimately seed yield.

Drymatter accumulation increased with increasing levels of nitrogen and phosphorus. Maximum drymatter accumulation was recorded with application of 60 kg N and 80 kg P_2O_5/ha and was significantly higher than their respective lower levels and control (Table 1).

Table 1 Drymatter accumulation, yield attributing characters, yield and response of soybean to different levels of nitrogen and phosphorus fertilization

Treatment	Drymatter accumulation (g/plant)	Yield attributing characters			Yield (kg/ha)		Equation	R^2 value	Economic optimum dose (kg/ha)	Expected yield (q/ha)
		Pods/ plant	Seeds/ pod	100-seed weight (g)	Seed	Straw				
Nitrogen levels (kg N/ha)										
0	19.17	40.55	2.95	12.27	1562	2448	Y=1586.7 + 34.43 x -0.37X²	0.9698	4550	2387
20	21.45	43.80	3.00	12.87	2202	3204				
40	23.02	47.65	3.15	13.30	2301	3401				
60	23.40	50.65	3.28	13.62	2353	3508				
SEm±	0.06	0.72	0.04	0.20	21	28				
CD (P=0.05)	0.18	2.09	0.12	0.59	61	82				
Phosphorus levels (kg P_2O_5/ha)										
0	21.02	37.25	3.00	12.27	1779	2473	Y=1775.3 + 10.863 x -0.05X²	0.9907	6583	2304
40	21.52	43.12	3.10	12.87	2099	3038				
60	22.02	48.80	3.84	13.30	2258	3282				
80	22.47	53.40	3.97	13.62	2282	3566				
SEm±	0.06	0.72	0.04	0.20	20	28				
CD (P=0.05)	0.18	2.09	0.12	0.59	61	82				

This could be ascribed to increased cell division and cell enlargement and better root growth which finally reflected into higher drymatter production. These results corroborate with the findings of Hanumanthapa *et al.* (1998) and Sexena *et al.* (2001).

Seed yield increased with increasing levels of nitrogen up to 40 kg N/ha but thereafter no marked increase was observed due to incremental increase in N dose (Table 1). The increase in seed yield due to application of 40 and 60 kg N/ha was 47.3 and 50.6%, respectively over no nitrogen application (control). Application of 80 kg P_2O_5/ha resulted in highest seed yield (2282 kg/ha) which, however, did not differ significantly from seed yield with 60 kg P_2O_5/ha (2258 kg/ha.

The increase in seed yield due to application of 60 and 80 kg P_2O_5/ha was 26.9 and 28.3%, respectively over no phosphorus application (control). This might be ascribed to beneficial effect of N and P application in the formulation of more number of pods/plant, seeds/pod and 100-seed weight which finally reflected in the shape of increased seed yield (Table 1). These results were in full agreement with the observations reported by Sexana *et al.* (2001) and Goswami *et al.* (1999). Interaction effect between nitrogen and phosphorus fertilization levels revealed that maximum seed yield (2524 kg/ha) was recorded with combined application of 60 kg N and 80 kg P_2O_5/ha (Table 2).

Table 2 ***Interaction effect of nitrogen and phosphorus fertilization on the seed yield of soybean***

Phosphorus levels (kg P_2O_5/ha)	Nitrogen levels (kg N/ha)				
	0	20	40	60	Mean
0	13.40	18.09	19.41	20.26	17.79
40	15.47	22.31	22.82	23.38	20.99
60	16.57	23.68	23.95	25.23	22.58
80	17.07	24.00	24.97	25.24	22.82
Mean	15.62	22.02	23.01	23.53	

SEm± = 0.42; CD (P=0.05) = 1.22

Response of soybean to N and P fertilization was found to be quadratic. The economic optimum dose was computed to be 45.50 kg N and 85.83 kg P_2O_5/ha for nitrogen and phosphorus, respectively at which the expected yield was found to be 2282 kg/ha and 2304 kg/ha.

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J. Oilseeds Res., **23(2) : 327-328 (2006)**

Short communication

Symbiotic attributes and productivity of soybean, *Glycine max* (L.) Merrill, as influenced by co-inoculation of plant growth promoting rhizobacteria with *Bradyrhizobium japonicum*

S.D. Billore, A.K. Vyas and O.P. Joshi

National Research Centre for Soybean, Indore-452 017, MP

(Received: August, 2005; Revised: February, 2006; Accepted: April, 2006)

Under intensive multiple cropping system, the nutrient balance becomes basic pre-requisite to ensure optimum production (Khan *et al.*, 2002). As such, need based fertilizer dressings will be required to replenish the exhausted nutrients based on the crop output. Their levels can be readjusted through microbial consortia inoculants along with organics. For improving crop yields, inoculation with specific microbial preparations is a common practice in many parts of the world. Several studies have shown significant increase in crop yields resulting from the addition of microbial cultures. Many plant associated bacteria synthesize plant hormones and growth regulators, which help in positively altering plant growth and development (Lindberg *et al.*, 1985; Frankenberger and Arshad, 1995) and have synergistic effects in plant protection (Chin *et al.*, 2003.) Looking at the beneficial effects of plant growth promoting rhizobacteria (PGPR), the present investigation was initiated to study the co-inoculation effects of PGPR with *Bradyrhizobium japonicum* (*B.j.*) on soybean.

A field experiment was conducted during *kharif*, 2002 and 2003 at National Research Centre for Soybean, Indore. The soil had pH 7.86, EC 0.14 dS/m, organic carbon 0.35%, available P_2O_5 11.0 kg/ha and available K_2O 280 kg/ha. The experiment was laid out in Randomized Block Design with three replications. The ten treatments included combinations of PGPR (PF 1- *Pseudomonas fluorescens* isolate-1, PF IV- *Pseudomonas fluorescens* isolate IV, Z-2- *Entrobacter* Spp., PV- *Proteus vulgaris*, Bs- *Bacillus sphaeriticus*, Kb- *Klbiesiella planticola*, RP 7 and RP 24- unidentified bacterial isolates) with *B.j.* and uninoculated control and *B.j.* alone. All the inoculants were received from Microbiology Division, IARI, New Delhi. Soybean (JS 335) was grown with 20:60:20 kg N:P_2O_5: K_2O kg/ha and other recommended package of practices. The nodule number and their dry biomass and plant biomass were recorded at flowering stage. The yield and yield attributes were recorded at maturity.

Symbiotic attributes: The seed inoculation with *B. j.* alone significantly increased the nodule number as well as their dry biomass over un-inoculated control (Table 1). Among the dual inoculation of *B. j.* and PGPR, except the combination with *Entrobacter* spp. rest all produced significantly higher number of nodules than un-inoculated control. The combination of *B. j.* with *Klbiesiella planticola* (130.3 mg/plant) and *Pseudomonas fluorescens isolate IV* (124.6 mg/plant) produced significantly higher nodule dry biomass than un-inoculated control, RP 24 and Z 2 but was at par with *B.j.* plus unidentified bacterial isolate (RP7) (117.2 mg/plant) and *B. j.* alone (115.5 mg/plant). This indicated that these isolates have complimentary effect on nodulation characteristics either by influencing the number or dry biomass.

Growth and yield attributing characters: In general, the effect of seed inoculation through *B. j.* or its combination with PGPR on shoot biomass, plant height and branches/plant was positive. The maximum value for shoot biomass was recorded with *B.j.* + PF 1 and for plant height and branches/plant with *B.j.* + *B.c.* However, this supplementary effect was more prominently visible in case of pods/plant and seed index (Table 1). All the combination treatments produced significantly higher number of pods per plant over un-inoculated control and *B. j.* alone (except *B. j.* plus *Pseudomonas fluorescens isolate IV*). *B. j.* alone and its combinations with PGPR except *B. j.* plus *Entrobacter* spp. resulted in significantly higher seed index over control. The seed index value of these combination treatments was although higher than *B. j.* alone treatment, *B. j.* in combination with *Pseudomonas fluorescens isolate IV*, *Bacillus sphaeriticus* and unidentified bacterial isolate (RP 7) showed significant differences.

Seed yield: Seed inoculation with *B. j.* alone and subsequent dual inoculation with PGPR had progressive additive effect on yield of soybean. However, the combination treatments remained at par with *B. j.* alone

but dual inoculation of *B. j.* with unidentified bacterial isolate (RP 7), *Pseudomonas fluorescens isolate 1*, *Entrobacter* spp. (Z-2), *Klbiesiella planticola* and *Proteus vulgaris* resulted in yields superior to un-inoculated control. It may be noted that seed inoculation with *B. j.* produced 9.3% higher yield as compared to un-inoculated control. Further improvement in seed yield with dual inoculation was to the tune of 2.3 to 13.5 % over *B. j.* alone.

The overall beneficial influence of inoculation with *B. j.* alone and coupled with PGPR on symbiotic traits, growth and yield has been reported earlier (Bhavsar and Chopade, 2003; Billore *et al.*, 2003). In the present investigation, similar influences were observed and the cumulative positive effects of treatments on nodulation characters and yield attributing characters, particularly in case of pods/plant and seed index were expressed in terms of enhanced productivity. Apart from these factors, the increased solubilization of macro- and micro- nutrients through siderophores also (Glick, 1995) and reduced population of deleterious microorganisms (Arshad and Frankenberger, 1998) are possible factors for enhancing the overall growth and yield of soybean.

The present investigation suggests that co-inoculation with *Bradyrhizobium japonicum* and PGPR had beneficial effect on soybean symbiotic traits, growth promotion and productivity of soybean.

Table 1 **Effect of co-inoculation of Bradyrhizobium and plant growth promoting rhizobacteria on yield attributes, symbiotic traits and yield of soybean (Pooled data)**

Treatment	Nodules/ plant	Nodule dry *mass* (mg/plant)	Shoot *biomass* (g/plant)	Plant *height* (cm)	Branches/ plant (No.)	Pods/ *plant* (No.)	Seed index (*g/100* seeds)	Seed *yield* (kg/ha)	Increase *over control* (%)	Increase over *B. Japonicum* (%)
Un-inoculated (control)	11.0	87.9	3.8	52	3	32	11.2	1662	-	-
Bradyrhizobium japonicum (*B.j.*)	23.2	115.5	5.0	54	3	33	12.1	1817	9.33	-
B.j. + *Pseudomonas fluorescens isolate-1* (PF 1)	37.2	83.9	7.1	55	4	46	12.7	2048	23.22	12.7
B.j. + *Pseudomonas fluorescens isolate IV* (PF IV)	63.4	124.6	6.6	55	3	37	12.9	1914	15.16	5.3
B.j. + *Proteus vulgaris* (PV)	23.9	65.3	5.1	56	4	40	12.7	1927	15.94	6.1
B.j. + *Bacillus sphaeriticus* (Bs)	28.9	84.0	6.4	61	4	40	12.9	1908	14.80	5.0
B.j. + *Klbiesiella planticola* (Kb)	34.9	130.3	4.8	57	3	42	12.4	1944	16.97	7.0
Unidentified bacterial isolate (RP 7)	33.0	117.2	6.8	55	3	44	12.8	2063	24.12	13.5
Unidentified bacterial isolate (RP 24)	22.4	55.6	6.1	53	3	43	12.6	1858	11.79	2.3
B.j. + *Entrobacter* Spp (Z-2)	14.6	61.4	4.1	52	3	42	11.6	1990	19.73	9.5
CD (P=0.05)	8.6	34.1	1.1	2.8	0.3	5.1	0.6	255	-	-

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J. Oilseeds Res., **23**(2) : **329-330 (2006)**

Short communication

Comparative performance of Indian mustard, *Brassica juncea* (L.) Czern & Coss based crop sequences in semi-arid Rajasthan : onfarm studies

O.P. Premi, S.K. Jha, Manoj Kumar, Fateh Singh, Y.P. Singh, N.S. Bhogal, A.K. Singh, A.K. Sharma and Arvind Kumar

National Research Centre on Rapeseed-Mustard, Sewar, Bharatpur-321 303, Rajasthan

(Received: May, 2005; Revised: October, 2005; Accepted: December, 2005)

Mustard bowl of India comprising parts of Rajasthan, Uttar Pradesh, Madhya Pradesh and Haryana has been predominantly practicing mono-cropping of mustard (fallow-mustard) resulting in not only the low cropping intensity and poor soil health but also the low net returns per unit area. Productivity and net returns from traditional fallow-mustard sequence can be improved by including *kharif* crops like pearl millet and black gram (Tomar and Tiwari, 1990; Yadav *et al*, 1995). Hence an attempt was made to assess the production potential and economic viability of mustard based crop sequences under semi-arid region of Rajasthan.

The experiment was conducted at twenty selected farmers' fields in the RFIVLP-17 (NATP) adopted village panchayat Khanua (Bharatpur), Rajasthan during *rabi* season of 2000-01 and 2001-02. Three mustard based crop sequences, *viz.*, pearl millet-mustard, black gram -mustard and fallow -mustard were evaluated at 10 farmers' fields (replications) with a plot size of 1000 m^2 each in the Randomized Block Design, in both the years. The rainfall received during the crop season 2000-01 and 2001-02 were 496.4 and 569.2 mm, which were 75% and 86% of the normal, respectively. On an average, the soil was sandy loam having 156, 9.5 and 383 kg available nitrogen, phosphorus and potash/ha, respectively. For the mustard, pearl millet and black gram crops, variety RH-30, HHB-67 and T-9 were used in both the years, respectively. The crops were fertilized as per the recommended doses of fertilizer for the area. For computation of productivity of a crop sequences, mustard seed equivalent yield (MSEY) was calculated on the basis of prevailing market prices of the produce. Land utilization index was expressed as percentage of days actually used in a year and was worked out by summation of duration of each crop in individual crop sequence divided by 365. Production efficiency value in terms of kg/ha/day was obtained by total production in a sequence divided by total duration of crop in that sequence.

The mustard seed yield was highest in fallow - mustard (1380 kg/ha) followed by black gram - mustard (1310 kg/ha) and pearl millet - mustard (1220 kg/ha) crop sequence (Table 1). This was due to the best moisture conservation during the kharif season in the fallow fields. These findings are in agreement with the finding of Yadav et al. (1995). However, the pearl millet- mustard crop sequence resulted in significantly higher mustard seed equivalent yield (1694 kg/ha) over black gram-mustard (1531 kg/ha), which was also significantly better than the traditional fallow-mustard sequence (1380 kg/ha). Sinsinwar *et al.* (2002) also obtained the maximum mustard seed equivalent yield with pearl millet-mustard crop sequence. This was mainly due to relatively higher land utilization index of 61.6 % for the pearl millet-mustard and 57.5 % in black gram-mustard sequence. The cropping intensity was doubled with the introduction of pearl millet and black gram in fallow-mustard sequence. The total productivity increases with the increase in cropping intensity (Tomar and Tiwari, 1990).

Table 1 Mean crop yield (kg/ha) and economics as influenced by different mustard based crop sequences

Crop sequence	Mean yield (kg/ha)			Mustard seed equivalent (kg/ha)	Additional net return over fallow-mustard (Rs/ha)	Production efficiency (kg/ha/day)
	Mustard	Pearl millet	Black gram			
Pearl millet-mustard	1220	1210	-	1694	2860	7.5
Black gram-mustard	1310	-	220	15431	1082	7.3
Fallow-mustard	1380	-	-	1380	-	9.2
SEm±	23.9	-	-	26.8	-	-
CD (P=0.05)	70	-	-	79	-	-

Note: Rates of farm produce/q: Mustard = Rs. 1250/-; Pearl millet = Rs. 465/- and Blackgram = Rs. 1260/-

The additional net return (ANR)/ha of Rs. 2860 and Rs. 1082 and ANR/ha/day of Rs. 12.7 and Rs. 5.2 accrued from the pearl millet-mustard and black gram-mustard crop sequences, respectively over the traditional fallow-mustard crop sequence. However, the fallow-mustard sequence with the shortest duration of 150 days and highest mustard seed yield (1380 kg/ha) had the highest production efficiency of 9.2 kg/ha/day, but the lowest land utilization index of only 41 % made it less remunerative in comparison to pearl millet-mustard and black gram-mustard sequences. Thus, mustard based crop sequence with low moisture requirement crop such as pearl millet during *kharif* season gave higher profitability under semi-arid region of Rajasthan.

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J. Oilseeds Res., 23(2) : 331-333 (2006)

Short communication

Effect of Zn and Fe enriched FYM application on mustard, *Brassica juncea* (L.) Czern and Coss yield and quality

M.C. Meena, K.P. Patel and D.D. Rathod

Micronutrient Project, Anand Agricultural University, Anand-388 110, Gujarat

(Received: May, 2005; Revised: September, 2005; Accepted: December, 2005)

Most of light textured soils of mustard growing area in middle and north Gujarat have been reported to be widely deficient in S and micronutrients especially in Zn and Fe (Patel *et al.*, 1999). The sustained productivity at high order could be maintained through integrated use of organics and inorganic fertilizers. The present study was aimed to assess the effect of Zn and Fe enriched FYM on crop yields, quality and Zn and Fe utilization by mustard.

A field experiment was conducted during 2002-03 on a sandy loam (Typic Ustochrept) Zn and Fe deficient soil having pH 7.8, organic carbon 0.21 %, available P_2O_5 48.5 kg/ha, available K_2O 222 kg/ha, DTPA-extractable Zn and Fe 2.90 and 0.34 µg/g, respectively. There were 18 treatments consisting of three levels of FYM and six levels of enrichment i.e., Zn and Fe with and without FYM enrichment at two levels of Zn (2.5 and 5.0 kg Zn/ha) and Fe (5.0 and 10.0 kg Fe/ha) as well as S at 20 kg/ha besides control replicated thrice in Factorial Randomized Block Design.

The half of the recommended nitrogen (50 kg/ha) and full dose of P_2O_5 (50 kg/ha) to the soil through urea and SSP + DAP as basal application were given to each plot. The S was maintained at 20 kg/ha in the treatments of Zn and Fe by selecting DAP and SSP as per the requirement. Based on the initial soil analysis, K_2O was not applied due to sufficient available potassium (K_2O) content in the soil. The required quantity of FYM was composted in pre-dung pit after mixing thoroughly mixed with 1% cow dung slurry and the solution of $ZnSO_4 .7H_2O$ and $FeSO_4 .5H_2O$ of required concentration corresponding to enrichment treatments viz., 2.5 kg Zn + 5.0 kg Fe and 5.0 kg Zn + 10.0 kg Fe through 500 kg of FYM/ha. The composting process was continued for seven weeks to fix the externally added inorganic Zn and Fe into organically bound and naturally chelated form of Zn and Fe; a process called as enrichment of FYM with Zn and Fe. The FYM used for enrichment contained total Zn and Fe as 58.5, and 639 µg/g, respectively. The total contents of Zn and Fe in FYM after enrichment under different levels i.e., Zn+Fe (2.5 + 5.0 kg), Zn+Fe (5.0 +10.0 kg) were 3852, 8480 and 8770, 18584 µg/g, respectively. The Zn and Fe enriched FYM was used to study its direct effect in mustard variety GM-2.

The seed samples were taken at the harvest of mustard for determination of total content of micronutrients. The oven dried seed samples were digested with HNO_3: $HClO_4$ (2:1) di-acid mixture and the extract was analysed for micronutrients, Zn, and Fe with atomic absorption Spectrophotometer (PE-3110) (Lindsay and Norvell, 1978). The oil content of mustard seed was determined by NMR analyzer (Model Oxford Analytical Instruments) and oil yield was computed. The protein content of mustard seed was worked out by multiplying nitrogen content of seed with a factor of 5.67 as suggested by Arora (1982).

Application of FYM and different levels of Zn and Fe i.e., 2.5 kg Zn + 5.0 kg Fe/ha and 5.0 kg Zn+10.0 kg Fe/ha through 500 kg FYM/ha significantly increased the yield of mustard over control (Table 1). The average increase in seed, straw and total yield due to FYM application was higher by 184, 356 and 539 kg/ha, respectively over no FYM. The seed yield improvement was maximum by 21% under En-Zn_2Fe_2 over NPS_0 (1890 kg/ha) followed by En-Zn_1Fe_1. Among the treatments, the Zn and Fe enriched FYM application showed more favourable effect in increasing mustard seed yield followed by NPS_1.

The beneficial effect of use of Zn and Fe enriched FYM was clearly noticed over straight Zn and Fe application as a direct effect in mustard. Among different treatments, enrichment proved to be superior in enhancing mustard yields. Thus, the increase in yield due to enrichment was higher by 12 % over straight application of Zn and Fe in mustard. The significant effect of Zn and Fe enriched FYM may be all micronutrients availability was expected to be enhanced through complexation or chelation and thereby prevented from reacting with soil properties (Gupta *et al.*, 1992; Latha *et al.*, 2001; Venkatasheshagiri *et al.*, 1994).

The application of FYM to mustard had significantly increased protein content and oil yield but oil content did not increase significantly over no FYM. The Zn and Fe treatments significantly influenced the oil, protein contents and oil yield. Oil content of seed was recorded as

minimum under NPS_0 and the maximum values were noted under Zn_1Fe_1. The differences in oil yield potential and protein contents due to En-Zn_2Fe_2 and En-Zn_1Fe_1 were not significant. The oil content, protein in seed and oil yield potential were increased by 5, 18 and 27% with En-Zn_2Fe_2 over NPS_0 (Table 1). Further, contents of oil, protein and oil yield were also found increased by 5, 6 and 13% due to S application over NPS_0.

The balanced nutrition of mustard by supplementation of deficient nutrients like Zn and Fe might have helped in enhancing oil and protein content and oil yield in mustard. The increase in oil content of mustard seed and potential oil yield due to Zn and Fe application has also been reported (Gauri Shankar *et al.*, 2002).

The data on content of Zn in mustard seed as affected by Zn and Fe treatments are given in Table 2. The Zn content of seed was found increased significantly due to effect of Zn and Fe application. A significant increase in Zn content of mustard seed was observed due to treatments of Zn and Fe application over NPS_0. Between two Zn and Fe enrichment levels, there was no significant difference in Zn content of mustard seed. The minimum uptake of 60.2 g/ha was recorded under NPS_0 while the higher values were recorded under En-Zn_2Fe_2 (90.6 g/ha) followed by En-Zn_1Fe_1.

The Fe content and uptake by mustard seed was found increased due to FYM application. The total Fe uptake by mustard was also significantly increased with FYM application (Table 2). In general, it was observed that content of Zn and Fe in mustard seed were higher under different treatments especially under Zn and Fe enriched FYM as compared to NPS_0. The Zn and Fe enriched FYM application showed its superiority in enhancing Zn availability and thereby higher content in mustard seed. The removal of Zn and Fe was higher due to their application over NPS_0. The improvement in overall mean total uptake of Zn and Fe by mustard due to Zn and Fe enriched FYM was higher by 14 % each respectively over straight Zn and Fe application.

The Zn and Fe enriched FYM caused higher utilization of Zn and Fe mainly due to its beneficial effects in mobilizing the native nutrients to increase their availability besides addition of Zn and Fe to the soil in naturally chelated form to provide better nutrition over longer time to cause better crop growth and thereby higher yields. (Chitdeshwari and Krishnaswamy 2000; Latha *et al.*, 2001).

Table 1 Effect of Zn and Fe application on yields and quality of mustard seed

Treatment	Yield (kg/ha)		Quality of seed		
	Seed	Total	Oil (%)	Oil yield (kg/ha)	Protein (%)
No FYM	1975	8614	36.38	721	21.74
5.0 t FYM/ha	2156	9177	36.39	786	22.14
10.0 t FYM/ha	2161	9128	36.34	787	23.21
CD (P=0.05)	73	328	NS	29.4	0.35
NPS_0	1890	8282	34.83	665	20.27
NPS_1	2069	8743	36.55	750	21.38
Zn_1Fe	2052	8757	36.91	765	22.13
En-Zn_1Fe_1	2249	9441	36.51	815	23.44
Zn_2Fe_2	2028	8907	36.74	745	23.05
En-Zn_2Fe_2	2297	9706	36.64	847	23.89
CD (P=0.05)	104	464	0.72	41.5	0.50

Table 2 Effect of Zn and Fe application on Zn and Fe content and uptake by mustard

Treatment	Zn			Fe		
	Seed		Total uptake (g/ha)	Seed		Total uptake (g/ha)
	Content (µg/g)	Uptake (g/ha)		Content (µg/g)	Uptake (g/ha)	
No FYM	34.5	68.75	94.4	60.1	119.8	1005
5.0 t FYM/ha	37.1	80.04	107.2	55.7	120.3	997
10.0 t FYM/ha	37.7	81.62	109.4	61.9	134.2	1217
CD (P=0.05)	1.8	4.17	5.6	NS	NS	82
NPS_0	31.7	60.17	83.6	55.3	104.4	983
NPS_1	33.8	70.15	95.1	60.3	125.0	995
Zn_1F_1	38.3	78.63	104.7	55.3	113.9	991
En-Zn_1Fe_1	38.1	85.56	114.0	59.4	134.1	1104
Zn_2Fe_2	37.3	75.73	102.0	58.6	119.0	1089
En-Zn_2Fe_2	39.5	90.60	122.5	66.4	152.1	1276
CD (P=0.05)	2.6	5.89	7.9	NS	20.3	115

The overall results indicate that Zn and Fe application to mustard caused significant improvement in seed, total yield and Zn and Fe content and uptake by mustard over control. Thus, the efficient use of Zn and Fe fertilizers was noticed when applied after enrichment over their straight application in inorganic forms. Since the increase at higher level was comparable with lower level, the Zn and Fe fertilizer application could be reduced to 2.5 and 5.0 kg/ha, respectively. The beneficial effect was mainly derived from their enrichment with FYM to cause improvement in nutrients availability and thereby use efficiency.

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J. Oilseeds Res., 23(2) : 334-335 (2006)

Short communication

Performance of mustard, *Brassica juncea* (L.) Czern & Coss in relation to varieties, spacing and nitrogen in northern plains

Jitendra Kumar Malik, Rajveer Singh, B.G. Shivkumar[1] and O.V.S. Thenua[2]

Department of Agronomy, Kisan Post-Graduate College, Simbhaoli, Ghaziabad, UP

(Received: September, 2005; Revised: February, 2006; Accepted: June, 2006)

Mustard, *Brassica juncea* (L.) Czern and Coss. is one of the most important oilseed crops cultivated in India. It occupies second place after groundnut with 4.52 m. ha. area and 3.92 m. t. production (Anonymous, 2004). However, the productivity is lower due to various factors, *viz.*, unsuitable variety, crop geometry, improper nutrition and lack of plant protection measures. Selection of variety suitable for the location, adapting better spacing based on the morphological features and crop nutrition, particularly of nitrogen are important to augment the productivity of mustard.

A field experiment was therefore carried out at Kisan Post Graduate College Farm at Simbhaoli, Uttar Pradesh during *rabi*, 2002-03. The soil of the experimental site was sandy loam in texture, neutral in reaction (pH 7.02) and low in organic carbon (0.28%), low in available nitrogen (178 kg/ha), medium in available phosphorus (22.4 kg/ha) and medium in available potash (135 kg/ha). The experiment was laid out in Split Plot Design and replicated thrice. The treatments comprised 2 row spacings *viz.*, 30 and 40 cm, in main-plots, and combinations of 2 varieties *viz.*, Pro agro 4001 and Pusa bold; and 3 levels of nitrogen *viz.*, 0, 40 and 80 kg/ha in sub-plots. Sowing was done on 4 October, 2002, irrigation and other cultural operations were followed as per recommended package of practices. The observations on growth parameters were recorded at regular interval and yield attributes and yield were recorded at harvest.

The plant height of mustard was significantly influenced by row spacing at 40 days after sowing (DAS) and at harvest, wherein a spacing of 40 cm between rows was significantly superior to 30 cm row spacing. But, both 30 and 40 cm row spacings were at par at 80 DAS. Chauhan *et al.* (1993) and, Buttar and Aulakh (1999) also reported that spacing had no effect on plant height. The varieties did not differ in plant height significantly at 40 and 80 DAS. But at harvest, Pro agro 4001 recorded significantly higher plant height as compared to Pusa bold (Table 1). This may be attributed to better vegetative growth in Pro agro 4001 even during reproductive phase. Increasing levels of nitrogen brought about significant increase in plant height at each incremental level up to 80 kg N/ha at all stages of growth. Nitrogen being an important structural component of plant tissues, the increased availability of N with increasing levels of applied nitrogen resulted in higher plant height. There was no significant difference between the row spacings on primary branches. However, the secondary branches were significantly higher with 40 cm row spacing. Which could be due to wider space available in 40 cm row as compared to 30 cm row spacing. The number of primary and secondary branches was significantly affected by increasing levels of nitrogen up to 80 kg/ha. Bhari *et al.* (2000) also reported significant increase in plant height, number of primary and secondary branches due to nitrogen application up to 120 kg/ha. Although 40 cm row spacing recorded higher dry matter accumulation at 40 DAS, as compared to 30 cm row spacing, but both the spacings were at par at later stages. There was no discernible variation in number of silique/plant, number of seeds/siliqua and test weight due to spacing. However, 30 cm row spacing recorded significantly higher harvest index and marginally higher length of siliqua. However, both 30 and 40 cm row spacings were statistically at par as far as seed yield was concerned.

The mustard variety Pro agro 4001 recorded significantly higher number of siliquae/plant and test weight as compared to Pusa bold. Consequently the seed yield of Pro agro 4001 was significantly higher as compared to Pusa bold. Other yield attributes *viz.*, length of siliqua, seeds per siliqua and harvest indices were at par in both the varieties. Varietal differences in yield attributes have also been reported by Singh and Singh (1998) and Patidar *et al.* (2000).

[1] Division of Agronomy, Indian Agricultural Research Institute, New Delhi-110 012.

[2] Department of Agronomy, Amar Singh Post-Graduate College, Lakhaoti, Bulandshahr, UP.

Table 1 Effect of varieties, spacing and nitrogen on growth and yield parameters, seed yield and harvest index of mustard

Treatment	Plant height (cm)			Branches/plant		Drymatter (g/plant)			Silique/ plant	Siliqua length (cm)	No. Of seeds/siliqua	Test weight (g)	Seed yield (kg/ha)	Harvest index (%)
	40 DAS	80 DAS	Harvest	Primary	Secondary	40 DAS	80 DAS	Harvest						
Row spacing (cm)														
30	27	166	191	10	25	2	12	50	479	5	19	5.4	1594	21.4
40	28	165	195	10	27	3	13	57	480	5	20	5.6	1560	19.6
S.Em ±	0.1	1.0	0.2	0.1	0.1	0.2	0.5	1.4	20.3	0.0	0.2	0.2	61	0.2
CD (P=0.05)	0.9	NS	1.5	NS	0.5	0.8	NS	NS	NS	NS	NS	NS	NS	1.4
Varieties														
Pro agro 4001	27	164	194	10	26	3	12	61	530	5	19	5.7	1631	20.6
Pusa bold	27	166	192	10	26	2	13	46	429	5	20	5.2	1523	20.5
S.Em ±	0.2	1.1	0.5	0.1	0.5	0.1	0.3	2.3	11.9	0.1	0.2	0.1	25	0.2
CD (P=0.05)	NS	NS	1.4	NS	NS	0.3	NS	6.8	35.1	NS	NS	0.3	74	NS
Nitrogen (kg/ha)														
0	26	154	188	9	22	2	10	40	366	5	19	5.2	1325	18.5
40	27	167	193	10	27	2	12	53	485	5	20	5.4	1620	20.5
80	28	174	198	11	29	3	16	68	587	5	20	5.8	1787	22.5
S.Em ±	0.2	1.4	0.6	0.2	0.6	0.1	0.4	2.8	14.6	0.1	0.3	0.1	31	0.9
CD (P=0.05)	0.7	4.0	1.7	0.5	1.6	0.4	1.2	8.3	42.9	0.4	0.8	0.4	91	0.6

Increasing levels of nitrogen from 0 through 80 kg/ha, recorded significantly higher siliquae/plant, length of siliqua, seeds/siliqua, test weight and harvest index with each incremental dose of nitrogen. Consequently the highest seed yield of mustard was observed with 80 kg N/ha followed by 40 kg N/ha. While the lowest seed yield was observed in no nitrogen treatment. The low inherent available soil nitrogen status resulted in increased growth attributes and yield parameters with increasing levels of nitrogen culminating in higher seed yield up to 80 kg/ha. Singh and Dixit (1989), Arthamwar *et al.* (1996) and Dalai *et al.* (1996) have also reported increased yield of mustard with increasing levels of nitrogen.

On the basis of this experiment, it may be concluded that there was no significant difference between 30 and 40 cm row spacing; Pro agro 4001 was significantly superior to Pusa Bold variety of mustard, and significantly higher seed yield of mustard could be obtained with application of 80 kg N/ha in northern plain zone.

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J. Oilseeds Res., **23**(2) : 336-339 **(2006)**

Short communication

Response of Indian mustard, *Brassica juncea* (L.) Czern & Coss to foliar application of zinc, boron and molybdenum

K. Tejeswara Rao and G. Subbaiah

Agricultural College, ANG Ranga Agril. University, Bapatla-522 101, AP

(Received: December, 2003; Revised: March, 2006; Accepted: June, 2006)

Mustard is an important oilseed crop in India, raised during winter season accounting for more than 75% of the area under rapeseed-mustard. The average oilseed productivity (815 kg/ha) of our country is quite low, compared with that of developed countries (2500 to 3000 kg/ha) and even below to world average (1500 kg/ha). Andhra Pradesh offers a great scope for expansion of area under mustard. The problem of micronutrient deficiency is becoming more serious with the introduction of HYV, increasing intensity of cropping, irrigation and usage of high analysis fertilizers. The usage of micronutrients in balanced fertilization has received comparatively less attention till recently. Foliar fertilization is simple and effective method for providing nutrients at peak periods of crop demand like full leaf expansion, pre-flowering and reproductive periods.

A field experiment was carried out during the *rabi*, 2001-02 at the Agricultural College Farm, Bapatla, located in Krishna-Godavari agro-climatic zone of Andhra Pradesh on clay loam soils. Initially the soil samples were processed and analysed for available macro and micro nutrients using standard methods as described by Jackson (1973). The soil of the experimental site was low in available nitrogen (278 kg/ha), medium in available phosphorous (14 kg/ha) and high in available potassium (608 kg/ha) having soil pH 7.7 available zinc 2.8 ppm (sufficient level), available boron 0.49 ppm and available molybdenum 0.06 ppm (deficient levels). The treatments comprised of recommended NPK alone, individual application. (Zn, B, Mo), combined application (Zn+B, B+Mo, Zn+Mo, Zn+B+Mo) of micronutrients along with recommended NPK, FYM alone (farmer's traditional practice), FYM along with the three micronutrients and the treatments were replicated thrice in Randomized Block Design. A uniform dose of P_2O_5 and K_2O at 60 and 40 kg/ha through SSP and MOP, respectively and FYM at 5 tonnes/ha were applied as basal as per treatments. Nitrogen at 120 kg/ha was applied in two splits one as basal and another at pre-flowering stage (30 DAS). Zn, B and Mo were sprayed as 0.5% $ZnSO_4$, 1.0 ppm borax and 0.1% ammonium molybdate, respectively. A spray fluid of 500 l/ha was used for foliar spray. The test cultivar of mustard used was Seeta. The crop was sown in the last week of November with a spacing of 45x10 cm between rows and plants. The gross and net plot sizes were 4.5m x 6.3m and 4.1m x 4.5m, respectively. The crop received three irrigations (including one pre sowing irrigation). Oil content in seed was analyzed by Nuclear Magnetic Resonance.

Effect on Growth Attributes: Significant difference in plant height and number of primary branches were noticed with different combinations of micronutrient over recommended NPK alone, FYM alone and individual application of micronutrients. The highest plat height (176 cm) and primary branches/plant (7.0) were recorded with Zn+B+Mo and B+Mo treatments respectively (Table 1). An increasing trend in values of dry matter production was recorded with the combined application of micronutrients. The highest (423.0 g/m^2) drymatter at harvest was recorded with Zn + B+ Mo, closely followed by B + Mo (422.8 g/m^2) and B (398.0 g/m^2) which were statistically on a par (Table 1). The increase in drymatter at harvest with Zn+B+Mo over recommended NPK alone and FYM alone was the extent of 16.4 and 43.4%, respectively. It might be due to better nutrition provided by micronutrients to the crop resulting in vigorous growth. With regards to 50% flowering the earliest flowering was noticed with micronutrient treatments over the recommended NPK alone. Treatment with Zn, Zn+Mo was statistically at a par with B, Mo, Zn+B, B+Mo which in turn were comparable among themselves. FYM applied treatment recorded the lowest number of days for 50% flowering and also maturity.

Effect on Yield Attributes: The yield attributes *viz.*, number of siliquae/plant, seeds/siliqua, thousand seed weight showed a marked increase with foliar application of micronutrients over recommended NPK and FYM alone (Table 2).

Higher number (245) of siliquae/plant were noticed with Zn+B+Mo. Higher number (13) of seeds/siliqua and 3.9g 1,000 seed weight were noticed with B+Mo treatment.

Boron plays a major role in better partition of assimilates from source to sink by way of sugar-borate translocation system. The siliquae/plant increased by 16%, seeds/siliqua by 20% and 1000 seed weight by 31% in B+Mo treatment compared with that of recommended NPK alone. Siliquae/plant increased by 24% with Zn+B+Mo over recommended NPK alone. Treatment with FYM showed the lowest values for all yield attributing parameters. All the micronutrient treatments were statistically on a par with regard to seeds/siliqua but superior to FYM. These results are in agreement with earlier findings of Patel *et al.* (1996); Abhijit Saha *et al.* (1999).

Seed Yield: Seed yield significantly increased with the foliar application of micronutrients. Combination of B+Mo resulted in higher seed yield. The percent increase in seed yield with B+Mo was 24.3 and 55.8, respectively over recommended NPK and FYM alone. The physiological basis for increase in seed yield was mainly due to increase in the yield attributes like number of siliquae/plant, number of seeds/siliqua and 1000 seed weight. This could further be supported by the positive and significant correlation between yield attributes and yield (r=0.70 to 0.98).

Additional seed yield obtained due to the addition of zinc, boron and molybdenum or their combination with each other over the recommended dose of NPK is presented (Fig.1) which clearly showed synergistic effect between B and Mo and also among B, Mo and Zn. An additional yield of 329 kg/ha was obtained with B+Mo followed by 289 kg/ha with Zn+B+Mo. It indicates synergetic effect in combined application of these nutrients. Among the individual nutrients, application of boron showed an additional yield of 117 kg/ha over recommended NPK alone.

Harvest index values showed superiority in all the micronutrient applied treatments over that of FYM applied treatments. Highest harvest index of 35.5% was recorded with Zn+Mo closely followed by B+Mo and Zn+B. Similar results were also reported by Singh and Singh (1984); Bora and Hazarika (1997). The lowest stover yield was noticed with FYM alone where as highest (2766 kg/ha) with Zn+B+Mo which was on a par with that of B+Mo, Zn, B, Mo treatments.

Table 1 Growth attributes of Indian mustard as effected by foliar application of micronutrients

Treatment	Plant height at maturity (cm)	No. of primary branches	Drymatter production (g/m^2)			Days to 50% flowering	Days to maturity
			45 DAS	60 DAS	At harvest		
Recommended NPK	144	5	142.7	251.7	353.7	32	81
Zn*	145	5	159.8	262.5	367.2	30	81
B*	150	6	170.8	295.8	398.0	28	79
Mo*	144	6	154.2	277.5	383.7	32	80
Zn+B*	170	6	158.5	258.9	377.3	29	80
B+Mo*	171	7	173.4	301.9	422.8	28	80
Zn+Mo*	166	6	142.0	254.0	363.9	31	81
Zn+B+Mo*	176	7	180.2	299.0	423.0	29	78
FYM (5 t / ha)	133	5	115.8	164.2	239.0	25	74
FYM + Zn+B+Mo	135	5	132.1	201.2	251.0	26	77
SEm ±	5.2	0.5	6.1	6.8	11.3	0.8	1.0
CD (P=0.05)	15.2	1.4	18.2	20.3	33.5	2.3	3.0

Treatments with (*) also received recommended NPK (120-60-40 kg/ha)
Zn, B and Mo were sprayed as 0.5% $ZnSO_4$, 1.0 ppm borax and 0.1% ammonium molybdate.
DAS - Days after sowing

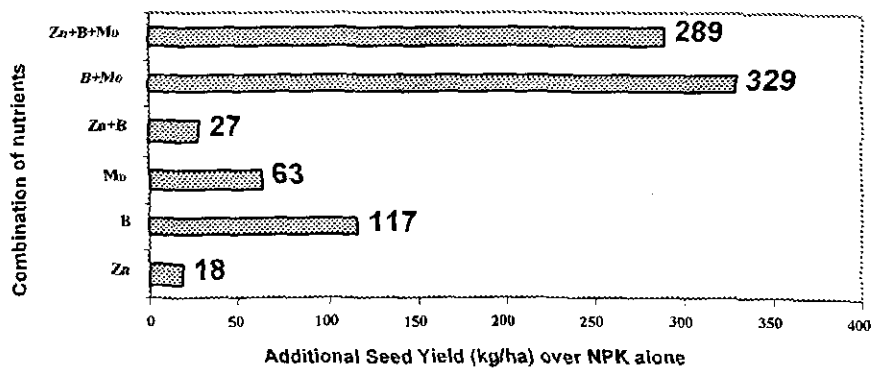
Table 2 **Harvest index, yield attributes, yield and mean oil content of Indian mustard as effected by foliar application of micronutrients**

Treatment	No. of Siliquae/ plant	No. of seeds/ siliqua	1000 seed weight (g)	Harvest index	Seed yield (kg/ha)	Stover yield (kg/ha)	Mean oil content (%)	Oil yield (kg/ha)
Recommended NPK	186	11	2.7	30.6	1020	2364	28.6	290.6
Zn*	191	11	2.9	29.5	1038	2478	30.7	306.5
B*	190	13	2.1	30.1	1137	2641	37.3	332.5
Mo*	190	11	2.9	29.5	1083	2581	20.7	310.5
Zn+B*	199	13	3.3	32.7	1047	2184	31.0	388.0
B+Mo*	221	13	3.9	33.3	1349	2710	32.2	422.6
Zn+Mo*	187	12	2.7	35.5	1011	1850	29.5	294.8
Zn+B+Mo*	245	13	3.4	31.9	1309	2770	33.5	413.5
FYM (5 t / ha)	161	9	2.7	26.4	549	1640	29.0	203.8
FYM + Zn+B+Mo	177	9	2.7	27.1	659	1700	29.3	208.4
SEm ±	0.82	0.8	0.2	2.7	99.2	132	-	24.7
CD (P=0.05)	24.4	2.5	0.6	8.2	294	391	-	73.5

Treatments with (*) also received recommended NPK (120-60-40)

Zn, B and Mo were sprayed as 0.5% $ZnSO_4$, 1.0 ppm borax and 0.1% ammonium molybdate.

Fig 1: Additional seed yield improvement over recommended NPK



Harvest index values showed superiority in all the micronutrient applied treatments over that of FYM applied treatments. Highest harvest index of 35.5% was recorded with Zn+Mo closely followed by B+Mo and Zn+B. Similar results were also reported by Singh and Singh (1984); Bora and Hazarika (1997). The lowest stover yield was noticed with FYM alone where as highest (2766 kg/ha) with Zn+B+Mo which was on a par with that of B+Mo, Zn, B, Mo treatments.

Oil Content and Oil Yield: Oil content increased with the combination of two and more micronutrients. Among the three micronutrients, boron has showed favourable effect over recommended NPK by recording 37.3% in oil content. The maximum oil content (33.5%) was recorded with Zn+B+Mo followed B+Mo with 32.2%. The higher oil content in these treatments was probably due to the participation of zinc and boron as essential constituents of volatile compounds and many enzymes (Lee and Arnoff, 1967) Molybdenum is associated with oxidation reduction reactions especially in the synthesis of fatty acids.

Oil yield was significantly influenced with the application of micronutrients. Higher oil yield due to combined application of B+Mo might be due to higher seed yield and consequent increase in oil per cent. Lower oil yield values were recorded with FYM treatment which might be due to lower seed yield in this treatment. Oil yield increased with the application of micronutrients indicating that oil yield is largely dependent on seed yield rather than oil content.

In conclusion the study revealed that the response of mustard yield to micronutrient was found to be higher over recommended NPK and FYM alone. Among the micronutrients boron and molybdenum showed positive influence on growth and yield. B+Mo combination along with recommended NPK dose (120-60-40 kg/ha) was found to be the best. It can also be concluded that for mustard crop application of FYM alone is not sufficient to meet the crop nutrient requirement on clay loam soils which are deficient in boron, molybdenum and sufficient in Zinc.

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J. Oilseeds Res., 23(2) : 340-341 (2006)

Short communication

Optimization of phosphorus management in soybean-safflower cropping sequence through integrated nutrient supply in vertisol

A.S. Dhawan, A.S. Karle, M.S. Deshmukh and B.B. Shendge

Department of Agricultural Chemistry & Soil Science, Marathwada Agricultural University, Parbhani-431 402, MS

(Received: July, 2005; Revised: October, 2005; Accepted: April, 2006)

Area under soybean crop is increasing day by day and at present it has occupied second place in the edible oilseed production in India. With the development of early maturing soybean varieties in the recent past it fits very well in the cropping system of Maharashtra and is highly remunerative. Soybean (*Kharif*) followed by safflower (*rabi*) has become a very popular system in vertisol where protective irrigation is available for *rabi* crop.

Both the crops being oilseed crops in soybean - safflower system, phosphorus requirement is relatively higher and hence phosphorus management holds the key to sustainability of cropping system. Low soil fertility and inadequate manuring are major causes of low yields of both crops. Oilseed legumes have relatively high phosphorus requirement as they play important role in metabolism of carbohydrates, proteins, lipids as well as in many oxidation - reduction reactions.

The existing system of nutrient management is based on the requirement of individual crop ignoring the residual and cumulative effect of fertilizer and manures applied to preceding crops. Owing to low P use efficiency of added and native phosphorus in soil an approach to phosphorus management in cropping system taking into account the residual and cumulative effect of phosphorus on crop nutrition holds the key to its efficient utilization.

Integration of chemical, organic and biological sources and their efficient management has shown promise in not only sustaining productivity and soil health but also in meeting a part of chemical fertilizer requirement of different crops and cropping system (Hegde, 1998). Hence the research work was carried out with an objective to optimize phosphorus management in soybean - safflower cropping sequence through chemical, organic and biological sources.

The present investigation was a superimposed study during the year 2002-2003 and was fifth cycle on long term experiment under All India Co-ordinated Research Project on Oilseeds being carried out at Department of Agronomy, Marathwada Agricultural University, Parbhani at fixed site since 1997-98. The experimental field was medium deep black soil (Typic haplustert) with pH 8.22, EC 0.36 dS/m, organic carbon 6.5 g/kg, available N , P and K 176, 12.8 and 247 kg/ha, respectively.

The design of experiment was Randomized Block Design comprising 12 treatments with four replication (Table 1). The recommended dose of fertilizer for soybean (*kharif*) was 30:60:30 and for safflower (*rabi*) was 60 : 40 : 0 N : P_2O_5 : K_2O, respectively. The soybean var. JS- 335 and safflower var. Sharada was used as test crops. The nitrogen was applied through urea and phosphorus through diammonium phosphate. The PSB culture was used through seed dressings as per the treatments.

Grain and straw yields of component crops were recorded plot wise. The P uptake was computed through grain and straw analysis for P content.

In soybean the highest grain yield was recorded under treatment T_{12} which was at par with T_2, T_7, and T_8 treatments (Table 1).

Similarly highest grain yield of safflower was observed under treatment T_2 (1649 kg/ha) where 100 % P was applied through chemical fertilizer to both crops in sequence, which was at par with T_7, T_8 and T_{11} (Table 2).

Straw yield was highest for soybean under treatment T_{11} where 100 % phosphorus was applied through chemical fertilizer and FYM to preceding crop and was at par with T_{10} and T_9. Highest straw yield of safflower is recorded under treatment T_2 where 100 % P was applied through chemical fertilizer to both the crops and was at par with T_3 (Table 2).

Highest P uptake through soybean was recorded in treatment T_2 where 100% phosphorus was applied through chemical fertilizer to both the crops in sequence, whereas, highest P uptake by safflower was observed under treatment T_8 where 100% P was applied through chemical fertilizers and FYM + PSB was applied to preceding crops. The treatments T_8 was at par with treatment T_7 (Table 2).

Table 1 Effect of phosphorus management treatments on phosphorus uptake (kg/ha) grain yield and straw yield (kg/ha) in soybean-safflower cropping sequence

Treatment	Soybean (*kharif*)				Treatment	Safflower (*rabi*)			
	Grain (kg/ha)	P uptake (kg/ha)	Straw (kg/ha)	P uptake (kg/ha)		Grain (kg/ha)	P uptake (kg/ha)	Straw (kg/ha)	P uptake (kg/ha)
T_1 : No P	1607	4.7	2112	2.5	No P	1128	2.1	1262	1.5
T_2 : 100% P	2063	11.4	2962	9.3	100% P	1649	6.9	1754	3.8
T_3 : 50% P	1862	6.7	2340	11.1	100% P	1389	5.8	1683	3.8
T_4 : 50% P	1811	7.1	2314	11.2	50% P	1305	3.9	1374	2.2
T_5 : 50% P	1895	9.7	2542	16.8	50% P + PSB	1370	5.3	1473	3.1
T_6 : No P	1651	4.9	2070	7.5	100% P	1285	5.5	1599	3.6
T_7 : 5 t FYM/ha	2026	8.9	2242	14.7	100% P	1588	6.7	1641	5.3
T_8 : 5 t FYM/ha + PSB	2047	9.4	2417	15.6	100% P	1600	6.7	1674	5.5
T_9 : 100% P	1965	11.0	3072	19.9	50% P	1400	4.3	1430	3.8
T_{10} : 100% P	1908	10.3	2988	19.5	No P	1175	2.3	1220	1.4
T_{11} : 100% P	1990	11.1	3114	20.3	5 t FYM/ha	1588	3.5	1296	2.0
T_{12} : 100% P	2097	11.1	2962	20.6	5 t FYM/ha + PSB	1400	4.4	1463	3.0
Mean	1910	8.6	2594	15.4		1406	4.8	1489	3.2
SEm±	45	0.14	23.43	0.16		87	0.03	16.47	0.02
CD (P=0.05)	129	0.39	64.85	0.45		242	0.07	45.59	0.06

Therefore, it is revealed that for optimization and economisation of phosphorus management in a cropping sequence soybean - safflower, application of 100 % P through chemical fertilizer can be skipped and replaced by FYM with or without PSB culture to one of the crops in sequence without sacrificing the yield levels. By way of integrating the phosphorus supply through organic, inorganic and bio fertilizer like PSB on cropping system basis the system productivity can be sustained. The synergy between organic, biofertilizer and chemical sources of phosphorus in cropping system could be harnessed through its positive residual and cumulative effect on crop nutrition. The number of evidences in the literature has appeared signifying the importance of integrated approach of phosphorus management in improving and sustaining the system productivity (Singaram and Kothandaraman, 1994; Bhatnagar *et al.*, 1996; Sharma and Vyas, 2002).

Acknowledgements: Authors would like to sincerely thank Dr. D. M. Hegde, Project Director, Directorate of Oilseeds Research Rajendranagar, Hyderabad for permitting to undertake superimposed studies on the ongoing long term experiment under AICRP on oilseeds to post graduate student of the Dept. of Agricultural Chemistry and Soil Science.

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J. Oilseeds Res., 23(2) : 342-343 (2006)

Short communication

Effect of cultivars, fertilizers and season on the seed and oil quality of sunflower, *Helianthus annuus* L.

G. Nagaraj and B.N. Reddy

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP

(Received: August, 2005; Revised: December, 2005; Accepted: December, 2005)

Sunflower due to its adaptability to all types of soils, climates and seasons, has emerged as an important oilseed crop of India within a short span after its introduction in India. It is an exhaustive crop and removes 63.3 kg N, 19.1 kg P_2O_5, 126.2 kg K_2O, 11.7 kg S, 68.3 kg Ca, 26.7g Mg, 47g Zn and 1075g Fe (Hegde, 1998). Thus, it is evident that fertilizer is vital for sunflower. In general, it is well known that the genotypes respond differently to fertilizers as well as seasons. Some information is available on the performance of different sunflower genotypes to fertilizer (Ankineedu *et al.*, 1983) and their quality (Nagaraj, 2003; Giriraj and Nagaraj, 2003). The present study is aimed at evaluating the quality of sunflower seed and oil under fertilizer treatments and seasons.

Field experiments were conducted at the Research Farm of Directorate of Oilseeds Research, Hyderabad during 2002-2004 on red sandy loam soil, low in N, P and medium in K. Three cultivars were selected *viz.*, Morden (variety), KBSH-1 and MSFH-17 (hybrids). Two fertilizer treatments were (i) no fertilizer and (ii) recommended dose of fertilizers (RDF) 60 kg N, 60 kg P_2O_5 and 30 kg K_2O. The two seasons were *kharif* (rainy season, July-October) and *rabi* (post-rainy - November to February). There were three replications under each treatment. The crop was grown as per normal package of practices (DOR, 2005). After harvest, seeds were collected. They were analysed for oil (NMR method) and protein (Kjeldahl N x 5.3). The oil was analysed for their fatty acid composition (Giriraj and Nagaraj, 2003). The data are presented in Table 1.

Table 1 Effect of genotype, fertilizers and season on sunflower seed and oil quality

Genotype	Treatment	Seed oil (%)	Seed protein (%)	Fatty acid composition (%)				Seed oil (%)	Seed protein (%)	Fatty acid composition (%)			
		Kharif, 2002											
				Palmitic	Stearic	Oleic	Linoleic			Palmitic	Stearic	Oleic	Linoleic
Morden	Fo	36.4	15.7	5.9	2.4	41.0	50.8	37.8	18.8	7.8	3.0	20.4	68.7
KBSH-1	Fo	42.9	15.9	5.8	2.5	46.4	45.5	42.4	18.2	7.6	3.2	23.8	66.0
MSFH-17	Fo	32.9	15.7	5.6	2.4	49.4	42.4	29.4	18.0	8.1	3.3	21.8	67.3
Morden	RDF	32.3	14.7	5.7	2.2	42.5	49.4	35.5	19.6	7.5	3.1	21.7	66.2
KBSH-1	RDF	38.3	15.5	5.7	2.4	46.7	45.3	29.3	18.3	7.9	3.4	21.2	67.6
MSFH-17	RDF	29.7	16.8	6.0	2.0	43.9	48.3	38.3	19.5	7.7	3.8	21.7	66.7
Mean		35.4	15.7	5.8	2.3	45.0	47.0	35.5	18.7	7.8	3.3	21.7	66.1
SEm±		2.2	0.3					1.0	0.3	0.4	0.4	0.9	
CD (P=0.05)		6.9	0.9					2.9	0.6	1.0	0.8	1.9	1.9
		Kharif, 2003						*Rabi*, 2003-04					
Morden	Fo	35.0	19.6	5.2	1.8	46.0	47.1	37.6	18.2	6.9	2.6	20.9	69.8
KBSH-1	Fo	41.5	18.8	5.3	1.8	46.6	46.2	43.0	17.2	7.2	3.0	21.6	68.3
MSFH-17	Fo	31.4	16.8	5.1	1.8	48.4	44.9	33.5	17.1	7.9	3.2	17.9	71.1
Morden	RDF	34.2	18.3	5.1	1.7	43.2	50.1	32.9	18.4	7.8	3.0	19.8	69.4
KBSH-1	RDF	43.3	20.0	5.2	1.9	47.2	45.7	41.4	17.6	7.3	2.8	20.0	70.2
MSFH-17	RDF	31.8	17.5	5.0	1.9	49.6	43.4	38.5	17.1	7.3	4.0	20.4	69.0
Mean		36.1	18.5	5.3	1.8	46.8	46.2	36.8	17.6	7.4	3.1	20.1	69.6
SEm±		1.0	0.7	0.2	0.2	1.9	1.9	1.7	0.4	0.4	0.2	1.7	1.4
CD (P=0.05)		2.0	1.6	0.4	0.4	4.2	4.0	3.7	0.8	0.9	0.5	3.5	3.0

Fo = No fertilizer; RDF = 60 kg N, 60 kg P_2O_5 and 30 kg K_2O

The oil content data revealed that KBSH-1 hybrid had higher oil content (41-43%) than the other two genotypes under no fertilizers, recommended dose of fertilizers and also in both the seasons. MSFH-17 hybrid had the lowest oil content (29-38%) while the variety Morden had medium level (32-38%). The protein content of the genotypes showed only marginal variations and the average levels ranged from 16-19% during both the seasons as well as under zero and RDF.

Fatty acid composition showed greater variation under the two seasons. *Kharif* sunflower seed oil had around 46% each oleic and linoleic acids. *Rabi* seed oil had 21% oleic and 68% linoleic acids. The lower temperatures that prevail during *rabi* season favour higher synthesis of linoleic acid, the polyunsaturated fatty acid (Mathur and Sharma, 1989). The desaturate enzyme activity becomes higher during low temperatures (*rabi*) and lower during higher temperature (*kharif*). Similar observations on the effect of temperature on sunflower (Nagaraj *et al.*, 1990) and niger (Nagaraj, 1994) oil quality have been made. Fertilizer application as well as genotypes did not have major influence on the fatty acid composition under a similar study but nitrogen application alone was found to increase the linoleic acid (Loubser and Grimbeck, 1985), while, P and K did not have any effect. In the present study all the fertilizers were applied together and hence no effect could be observed.

The present study thus reveals that for obtaining more nutritious sunflower oil, richer in linoleic acid (the essential fatty acid), it is better to grow the crop under *rabi* conditions in and around Hyderabad.

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J. Oilseeds Res., 23(2) : 344-345 (2006)

Short communication

Effect of biofertilizers on the performance of sunflower, *Helianthus annuus* L. cv. CO 4

A. Rubapunithavathy, S. Natarajan, M. Ganapathy and K. Arivazhagan

Department of Agronomy, Annamalai University, Annamalainagar-608 002, TN

(Received: August, 2005; Revised: April, 2006; Accepted: June, 2006)

Sunflower occupies a predominant place among oilseed crops because of its good quality oil. Compared to world productivity of sunflower seeds, the productivity in India is very low (Hegde, 2002). Judicious and timely application of nutrients is one of the agronomic practices to improve the sunflower yield. In this context, as the cost of fertilizers is mounting besides its continuous use results in damaging the soil health and causing environmental pollution, replacing part of the chemical fertilizers with biofertilizers is an apt alternative strategy. The importance of biofertilizers, *viz.*, *Azospirillum* and *Azotobacter* in increasing the growth and yield of sunflower was well established (Sivakumar, 1994). Hence a field investigation was carried out to study the effect of *Azospirillum* and *Azotobacter* on the growth and yield of sunflower.

The experiment was conducted at Annamalai University Experimental Farm, Annamalainagar, during summer and *kharif*, 2004 in clay loam soil to study the response of sunflower cv. CO 4 to different levels of N and biofertilizers. The soil was low in available N (231.0 kg/ha), medium in available P (17.7 kg/ha) and high in available K (316.2 kg/ha). The experiment consisted of nine treatment combinations of chemical fertilizers and biofertilizers (Table 1). The fertilizer schedule used in the study was 40:20:20 NPK kg/ha. *Azospirillum* and *Azotobacter* were applied as seed treatment @ 600 g/ha as per treatment schedule. Phosphorus and potassium was applied uniformly to all the plots. The experiment was laid out in Randomized Block Design with three replications. Entire P was given at basal, N and K each were split into two doses *viz.*, 50% at basal and 50% at 30 days after sowing (DAS). A spacing of 30 cm x 30 cm was maintained between rows and plants.

Table 1 Effect of biofertilizers on growth and yield of sunflower (Cv. CO 4)

Treatment	Drymatter production (kg/ha)		Head diameter (cm)		Filled seeds/capitulum		Seed yield (kg/ha)		Net returns (Rs/ha)		B:C Ratio	
	Season-I	Season-II	Season-I	Season-II	Season-I	Season-II	Season-I	Season-II	Season-I	Season-II	Season-I	Season-II
No Nitrogen	3425	3418	14.42	13.52	432	396	980	950	4091	3613	1.35	1.31
50% Nitrogen	3480	3442	16.61	15.68	510	476	1130	1102	6286	3837	1.53	1.49
100% Nitrogen	3734	3731	22.80	21.76	901	870	1851	1752	17607	16021	2.46	2.33
Azospirillum Seed treatment	3576	3525	18.76	17.28	637	610	1293	1252	9726	9058	1.88	1.82
Azotobacter Seed treatment	3541	3502	17.74	16.32	579	547	1225	1201	8634	8254	1.78	1.75
Azospirillum + *Azotobacter* Seed treatment	3621	3610	19.78	18.37	698	667	1396	1359	11342	10760	2.03	1.97
50% Nitrogen +*Azospirillum* Seed treatment	3668	3660	21.74	20.70	830	806	1593	1546	13576	12839	2.13	2.07
50% Nitrogen + *Azotobacter* Seed treatment	3647	3625	20.75	19.68	776	745	1495	1453	12020	11350	2.00	1.95
50% Nitrogen + *Azospirillum* + *Azotobacter* Seed treatment	3736	3733	23.03	22.04	927	897	1884	1782	18216	16582	2.52	2.38
CD (P = 0.05)	3	3	0.6	0.6	51	47	35	33				

Season I = Summer; Season II = *Kharif*

Largest drymatter production at harvest stage was produced with 50% N + *Azospirillum* + *Azotobacter* seed treatment which was comparable to that of 100%N and the increase being 67% over control (Table 1). *Azospirillum* and *Azotobacter* inoculation enhanced the activity of growth promoting substances besides assisted in N fixation and provided the essential nutrient in available forms (Kumar *et al.*, 2000; Nandhagopal *et al.*, 2003).

The highest seed yield was recorded with 50% nitrogen + *Azospirillum* + *Azotobacter* seed treatment and it was comparable with that of 100% nitrogen. Next higher seed yield was with 50% nitrogen + *Azospirillum* seed treatment and the lowest seed yield was obtained with no nitrogen. Supply of nutrients readily in available form through chemical fertilizers and slow steady release of nutrients through biofertilizers would have helped in attaining higher seed yield through increased heading and more number of filled seeds/capitulum with 50% N + *Azospirillum* + *Azotobacter* seed treatment. Venkatakrishnan and Balasubramanian (1996) earlier reported the beneficial advantage of nitrogen and biofertilizer in augmenting the yield components of sunflower.

Highest net return was obtained with 50% N+*Azospirillum* + *Azotobacter* seed treatment. Likewise, highest benefit cost ratio of Rs. 2.52 was obtained with 50% N + *Azospirillum* + *Azotobacter* seed treatment while 100% N it was Rs.2.46. The cheaper source of nutrients with *Azospirillum* and *Azotobacter* resulted in higher benefit cost ratio.

The study clearly indicated the synergistic and positive effect of combined application of *Azospirillum* and *Azotobacter* in replacing the chemical nitrogen to an extent of 50% to attain higher seed yield comparable to that of 100% chemical nitrogen.

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J. Oilseeds Res., 23(2) : 346-347 (2006)

Short communication

Nutrient management in irrigated castor, *Ricinus communis* L. through integrated approach in Rajasthan

I. Singh, M.S. Rathore, M.S. Chandawat and D.S. Rao

Agricultural Research Station, Rajasthan Agricultural University, Mandor-342 304, Jodhpur, Rajasthan

(Received: December, 2005; Revised: April, 2006; Accepted: June, 2006)

Castor, *Ricinus communis* L. offers an important industrial oil, which is completely biodegradable. Castor cake is an excellent organic manure also. Gujarat and Rajasthan contribute 88% of the total castor production in our country and share 60% of the total castor growing area. The castor productivity in Rajasthan is quite low (1482 kg/ha) as compared with neighbouring state of Gujarat (2000 kg/ha). Poor nutrient management is one of the major reasons for low productivity of castor raised in the nutrient poor light textured soils of Rajasthan. Imbalanced use of in-organic sources of nutrients has detrimental effect on soil health. Therefore, partial fulfillment of the nutrient requirement through organic sources has become necessary (Gosh *et al.*, 2002). Information on the effect of organic sources like cakes, bacterial cultures, *in situ* green manuring and FYM on castor is meager. Hence this trial was conducted.

The field experiment was carried out during the rainy (*kharif*) and winter (*rabi*) seasons of 2002-03 and 2003-04 at the Agricultural Research Station, Mandor (Rajasthan). The soil of the experimental site was loamy sand in texture, alkaline in reaction (8.2 pH), low in organic carbon (0.20%), medium in available phosphorus (23 kg P_2O_5/ha) and rich in available potassium (365 kg K_2O/ha). Twelve treatments consisting of different combinations of recommended dose of fertilizers and organic products were laid out in Randomized Block Design with three replications (Table 1). The net plot size was 4.8 m x 5.4 m. FYM and castor cake were incorporated in plots as per treatment at the time of seedbed preparation. In the treatment of in situ green manuring, clusterbean variety RGC-936 was sown @ 30 kg seeds/ha in the inter row spaces of castor and was incorporated in soil at 55 days after sowing. The seeds, as per treatment were inoculated with *Azospirillum* @ 100 g/kg seed before dibbling. Phosphorus solublizing bacteria @ 600 g/ha were mixed with farmyard manure and applied in rows at the time of sowing as per treatment. Half of the total N and full dose of phosphorus as per treatment were applied as basal dose and the remaining N was applied in two equal splits at 35 and 90 days after sowing with irrigation. Castor variety "GCH 5" was dibbled @ 6 kg seeds/ha in furrows at 120 cm row and 90 cm plant spacing on 14 August, 2002 and 20 July 2003. Seven irrigations were applied to crop at 20 days interval starting from 55 days after sowing. Two extra irrigations were given during 2002-03 to save the crop from severe drought. Two hoeing cum weeding operations were done at 20 and 40 days growth stages to check weeds. The crop was harvested in five pickings at 30 days interval starting from 90 days after sowing. Total rainfall received during crop pendency in kharif 2002-03 and 03-04 were 52 and 344 mm, respectively.

Plant height up to main raceme was improved significantly with application of 75% RDF + 25% N through FYM + *Azospirillum* (S.T.) + PSB culture, compared with 100 % RDF (Table 1). In situ green manuring of clusterbean + 75 % recommended dose of fertilizers proved beneficial as it gave 14.1 and 14.7% higher seed and oil yield respectively over castor grown with 75 % RDF without *in situ* green manuring. Castor, being a long duration crop fully utilized the readily available nutrients from green manure and in turn produced higher seed and oil yield. In situ green manuring of clusterbean + 75 % RDF gave net return of Rs. 28817/ha which was more than 75 % RDF by Rs. 4980/ha.

Substitution of 25 % N through organics like FYM and Castor cake also proved better as the seed yield observed with 75 % RDF + 25 % N through castor cake (2701 kg/ha) and 75 % RDF + 25 % N through FYM (2707 kg/ha) were found significantly superior to 75 % RDF and remained comparable with the seed yield obtained from 100 % RDF. The oil yield with these treatments improved significantly by 195 and 203 kg/ha over 100 % RDF.

Maximum improvement in the performance of castor was observed with FYM application in conjunction with bio-fertilizers. Application of 75 % RDF + 25 % N through FYM + *Azospirillum* (S.T.) + PSB culture produced the highest seed and oil yield of 2816 and 1366 kg/ha, respectively. This treatment improved the seed yield by 18.7 and 26.2% over 75 and 50 % RDF, respectively.

Yield and yield components: In stress 1 i.e., when stress was imposed from 30-90 DAS, primary spike yield is more affected with stress (Table 3). There was 25.3% reduction in effective spike length, 32.3% reduction in capsule number and 44.7% reduction in capsule weight there by 44% reduction in seed weight. Secondary branch production increased after relieving stress and secondary seed yield was more in stress (22%) than control due to increased spike length, capsule no. per spike, capsule weight and seed weight.

In stress 2, where stress was imposed from 60-120 DAS, primary spike was not much affected and the yield reduction was only 5.6% compared to control. But *secondary spike growth, capsule number and capsule* weight were affected due to stress. There was 17.6% reduction in seed weight/plant. Tertiary spike yield was significantly reduced (50.1%) due to the stress from 60-120 DAS. On the whole, there was 26.1% reduction in seed yield with stress 1 and 35.4% reduction in stress 2. Ravishanker *et al.* (1991) also reported reduced seed yield and TDM with stress from 41-71 days in sunflower. Seed yield was markedly reduced when water stress occurred during either the vegetative phase or during the early *stages of flowering. Data suggests that castor crop is* more sensitive to stress from 60-120 DAS compared to stress from 30-90 DAS. Irrigated castor gave 42% higher seed yield than the rainfed castor (Subba Reddy *et al.*, 1996).

Table 1 List of germplasm lines studied

Pest tolerant lines	Temperature tolerant lines	Temperature susceptible lines
RG 89,109,111,224,297,398, 707,724,1427,1607,1608,1624, 1628,1922,2046,2048,2694,2706, 2708,2710,2718,2725,2726,2727, 2730,2731,2732,2733,2734	RG 68,77,78,122,156,161, 168,214,226,232,235,236, 242,245,246,293,295,297, 298,302,332,337,360,614, 803,900,1096,1117,1192,1815	RG 661,898,1310,1449, 1526,1687

Table 2 Growth before and after reliving stress

Character	Stress (30-90 days)			Stress (60-120 days)		
	BIS	BRS	ARS	BIS	BRS	ARS
Plant height (cm)						
Control	23.8	63.8	64.2	42.0	64.2	64.4
Stress		48.0	50.8		55.0	55.1
Leaf number						
Control	6	10	14	9	14	17
Stress		7	17		9	19
Sec. branches						
Control	0	3	5	3	3	5
Stress		2	4		3	5
Tert. branches						
Control	0	1	3	1	3	5
Stress		0	3		1	3
Quart. branches						
Control	0	0	4	0	3	4
Stress		0	3		1	4

BIS : Before imposing stress; BRS : Before reliving stress; ARS : After reliving stress

Table 3 Yield and yield components

Character	Stress from 30-90 DAS			Stress from 60-120 DAS		
	Control	Stress	% reduction	Control	Stress	% reduction
Primary spike						
Spike length(cm)	28.1	20.1	28.5	28.1	23.8	15.3
ESL	18.2	13.6	25.3	18.2	15.9	12.6
Capsule no./plant	31	21	32.3	31	27	12.9
Capsule wt. (g/plant)	39.8	22	44.7	39.8	30.4	23.6
Seed wt. (g/plant)	25	14.1	43.6	25	18.4	5.6
Secondary spike						
Spike length(cm)	15.6	17.7	-13.5	15.6	12.2	21.8
ESL	9.7	11.6	-19.6	9.7	8.7	10.4
Capsule No./plant	12	15	-25	12	9	75
Capsule wt. (g/plant)	36.6	40.5	-10.7	36.6	30.3	17.2
Seed wt. (g/plant)	22.7	23.2	-22.0	22.7	18.7	17.6
Tertiary spike						
Spike length(cm)	10.5	10	4.8	10.5	6.5	38.1
ESL	6.8	6.4	5.9	6.8	4.5	33.8
Capsule No./plant	10	7	30	10	5	50
Capsule wt. (g/plant)	40.5	30.2	25.4	40.5	20.2	50.1
Seed wt. (g/plant)	23.7	15.8	20.5	23.7	10.4	56.8
Quaternary yield	0.4	0.0	100	0.4	0.0	100
Total seed wt. (g/plant)	71.9	53.1	26.1	71.9	46.9	35.4

The total seed yield of different lines surviving drought, per cent reduction in stress and DSI values were presented in Table 4. Lines RG89, 77, 111, 122, 214, 224, 232, 247, 293, 295, 297, 298, 332, 337, 398, 707, 724, 803, 1117, 1427, 1449, 1526, 1815 showed <30% yield reduction in stress 1. Lines RG 89, 122, 214, 232, 236, 246, 297, 298, 332, 707, 724, 900, 1117, 1449, and 1526 showed <30% yield reduction in stress 2. Twelve lines showed drought tolerance with <30% yield reduction in both stresses. These lines include RG 89, 122, 214, 232, 297, 298, 332, 707, 724, 1117, 1449, and 1526.The lines with <0.5 drought susceptibility index (DSI) in stress 1 are RG 89, 111, 122, 293, 297, 298, 332, 707, 1117, 1815, 1449 and lines with <0.5 DSI in stress 2 are RG 122, 214, 298, 332, 724, 900. The genotypes with low/moderate DSI (<0.7) were considered least drought susceptible in wheat also (Chowdhury *et al.*, 1988). Out of 31 lines that showed tolerance to temperature in lab, 9 lines showed tolerance even in the field. These lines include RG 122, 214, 232, 293, 297, 298, 332, 1117, and 1815. The lines RG 122, 298 and 332 showed better tolerance in lab and also in field with <30% yield reduction and with low DSI values in both stresses.

Table 4 Total seed yield and drought susceptibility index (DSI) of different germplasm lines

Germplasm	Total seed yield/plant			% reduction		DSI	
	Stress1	Stress2	Control	Stress1	Stress2	Stress1	Stress2
RG89	49.5	32.2	43.2	-14.7	25.4	-0.56	0.73
RG109	27.8	29.0	82.2	66.1	64.7	2.53	1.87
RG111	34.3	15.9	34.5	0.6	54.0	0.02	1.56
RG224	60.4	32.8	81.3	25.7	59.7	0.98	1.72
RG297	78.3	39.0	51.8	-51.2	24.8	-1.96	0.72
RG398	49.9	38.5	58.4	14.6	34.1	0.56	0.98
RG707	90.2	57.9	77.0	-17.0	24.8	-0.65	0.72
RG724	73.8	90.4	101.6	27.3	11.0	1.05	0.32
RG1427	43.7	35.9	53.6	18.6	33.1	0.71	0.96
RG1607	7.5	6.4	11.5	34.9	44.6	1.34	1.29
RG1608	24.9	24.3	62.8	60.3	61.3	2.31	1.77
RG1624	22.6	20.8	55.8	59.5	62.8	2.27	1.81
RG1628	27.1	34.8	75.6	64.2	54.0	2.46	1.56
RG2730	25.1	35.9	80.1	68.7	55.2	2.63	1.60
RG68	68.3	51.7	99.9	31.6	48.3	1.21	1.40
RG77	46.1	40.7	62.6	26.4	35.0	1.01	1.01
RG122	79.1	94.8	84.3	6.2	-12.5	0.24	-0.36
RG161	15.5	10.8	102.5	84.8	89.5	3.24	2.59
RG214	58.4	91.1	74.9	21.9	-21.7	0.84	-0.63
RG232	44.7	48.1	59.7	25.2	19.6	0.96	0.57
RG236	35.7	67.2	86.6	58.8	22.3	2.25	0.65
RG242	32.0	36.4	62.8	49.1	42.0	1.88	1.21
RG246	38.4	55.8	72.7	47.2	23.2	1.80	0.67
RG247	75.8	61.5	90.4	16.2	32.0	0.62	0.92
RG293	87.0	56.2	95.8	9.2	41.3	0.35	1.19
RG295	55.6	39.5	66.1	15.9	40.3	0.61	1.16
RG297	86.0	68.9	71.8	-19.9	4.0	-0.76	0.12
RG298	52.0	68.4	49.1	-5.9	-39.3	-0.23	-1.14
RG302	86.5	54.9	128.1	32.4	57.1	1.24	1.65
RG332	82.9	67.2	74.9	-10.7	10.3	-0.41	0.30
RG337	69.9	52.5	98.0	28.7	46.4	1.10	1.34
RG360	52.4	40.8	83.2	37.0	50.9	1.42	1.47
RG803	55.2	42.7	66.3	16.8	35.6	0.64	1.03
RG900	60.8	97.2	94.7	35.8	-2.6	1.37	-0.08
RG1096	32.7	28.6	51.0	35.8	43.9	1.37	1.27
RG1117	83.6	61.7	80.8	-3.5	23.7	-0.13	0.68
RG1815	84.6	51.4	86.5	2.3	40.6	0.09	1.17
RG661	25.4	20.9	69.4	63.4	69.9	2.43	2.02
RG1449	74.7	50.0	61.3	-21.9	18.4	-0.84	0.53
RG1526	57.8	56.6	72.7	20.5	22.1	0.78	0.64
RG1687	20.5	15.8	31.7	35.5	50.2	1.36	1.45
Average	53.1	47.0	71.9	24.3	34.1	0.93	0.99

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J. Oilseeds Res., **23**(2) : **353-355 (2006)**

Short communication

Screening castor, *Ricinus communis* L. germplasm lines for thermal tolerance

P. Lakshmamma and Lakshmi Prayaga

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP

(Received: July, 2005; Revised: June, 2006; Accepted: August, 2006)

Under natural conditions, abiotic stress is imposed gradually, so plants experience a sub lethal stress before the severe stress. The plants which are capable of adapting to the changing environment at sub lethal stress can perform better under the severe stress by undergoing some changes at cellular level during sub lethal stress which is referred as acquired tolerance (Hahn and Li, 1990). During the sub lethal stress, several stress responsive proteins are expressed which in turn trigger several physiological and biochemical parameters relevant for stress tolerance. The genetic variability in gene expression upon induction stress is responsible for the differential survival and recovery following exposure to severe lethal stress in a heterogeneous population.

There is lack of suitable technique for screening for stress tolerant lines. An efficient technique called Temperature Induction Response technique was developed by Kumar *et al.* (1999) for identifying high temperature tolerant lines in sunflower. Optimization of induction and subsequent lethal temperature levels is a pre requisite for developing a standardized screening protocol. Optimum lethal temperature is the temperature treatment and duration, which causes 80% reduction in growth in non-induced seedlings compared to control. Optimum induction temperature is the temperature treatment and duration in which maximum recovery growth is observed at optimum lethal temperature. The optimum induction and lethal temperatures were not worked out for castor. Identifying temperature tolerant lines in a large germplasm at seedling level helps in utilizing these germplasm lines in hybrid breeding programme for developing stress tolerant lines. Hence an experiment was conducted to standardize optimum induction and lethal temperatures for castor and screening of germplasm lines for temperature tolerance through this technique.

Standardization of optimum induction and optimum lethal temperature for castor

The pre imbibed castor seeds were germinated in Petri dishes at room temperature. The germinated seedlings of approximately 1 cm plumule length were used to study the genetic variability in stress response.

Optimum lethal temperature: Optimum lethal temperature is the temperature treatment and duration, which causes 80% reduction in growth in non-induced seedlings compared to control. Different temperatures ranging from 45-50°C for 2 h and 3 h were tried 5 times with 3 replications. Temperatures above 48°C recorded 100% death of seedlings, where as at 48°C the mortality was 88% when exposed for 2 h and it was 98% when exposed for 3 h. So optimum lethal temperature for castor was fixed at 48°C for 2 h.

Optimum induction temperature: Temperature treatment and duration in which maximum recovery growth is observed at optimum lethal temperature. Different temperatures and different durations ranging from 35°C for 1 h to 45°C for 2 h in different combinations were tried in replications for standardizing optimum induction temperature in castor. Optimum induction temperature was fixed at 35°C for 2 h followed by 40°C for 2 h, 45°C for one h and then exposing it to optimum lethal temperature. Percent seedling survival was >90 i.e. maximum with this temperature in castor. Optimum induction and lethal temperatures were fixed similarly in sunflower by Kumar *et al.* (1999).

Recovery growth: After the lethal and induction temperature treatments, the seedlings were allowed to recover at room temperature for 72 h. At the end of recovery period, percent seedling survival was recorded. In all these treatments, twenty seedlings were used per replication and replicated thrice.

Identification of thermo tolerant lines by TIR technique: One hundred and ninety castor germplasm lines were screened during 2000-02, to identify thermo tolerant lines. Among these, the germplasm lines with acquired tolerance to stress and susceptible lines are listed in Table 1.

Acquired tolerance with induction is shown in Fig 1. This shows that when plants are exposed to sub lethal stress, stress responsive proteins are expressed and they impart tolerance. Genetic variability for stress tolerance is seen only upon optimum induction stress. These tolerant lines

need to be tested in field for reconfirmation of their tolerance capacity. In sunflower, the seedlings that showed tolerance at seedling level also showed higher tolerance at plant level, when an open pollinated population was subjected to high temperature stress. Upon optimum induction, considerable variation for recovery was seen indicating the persistence of this acquired selected trait (Kumar *et al.*, 1999). This tolerance was associated with accumulation of heat shock proteins (Vierling, 1991; Nguyen *et al*, 1992). The synthesis and localization of some of these HSPs trigger several important physiological and biochemical parameters (Chen *et al.*, 1990). These changes facilitate the maintenance of cellular function under stress.

Table 1 Screening castor genotypes for thermo tolerance

Category	No. of lines
>70% recovery growth with induction	44
>80% recovery growth with induction	31 RG 68, RG 77, RG 78, RG 122, RG 156, RG 161, RG 168, RG 214, RG 226, RG 232, RG 235, RG 236, RG 242, RG 245, RG 246, RG 247, RG 293, RG 295, RG 297, RG 298, RG 302, RG 332, RG 337, RG 360, RG 614, RG 803, RG 900, RG 1096, RG 1117, RG 1192 and RG 1815.
>70% recovery growth with induction and lethal	10
>80% recovery growth with induction and lethal	8 RG122, RG 226, RG 232, RG 235, RG 242, RG 247, RG 1096 and RG 1117
>70% alive at lethal	9
>80% alive at lethal	5
>70% death with induction	12
>80% death with induction	12 RG 92, RG 128, RG 171, RG 181,RG 222, RG 530, RG 1310, RG 1384, RG 1389, RG 1449, RG 1526 and RG 1687
>70% death at lethal	87
>80% death at lethal	43
>70% death with induction and lethal	20
>80% death with induction and lethal	7
>70% recovery growth with induction & >70% death at lethal	7
>80% recovery growth with induction & >70% death at lethal	3
>80% recovery growth with induction & >80% death at lethal	0

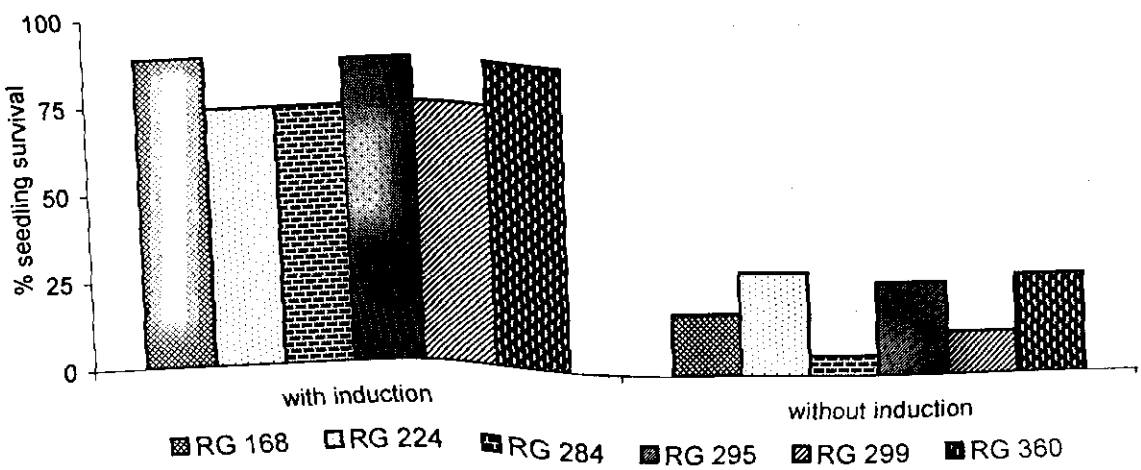

Fig. 1 Genetic variation for recovery per cent under stress

In general, the expression of stress induced genes and subsequent physiological changes occur predominantly during induction stress. Therefore, the seedlings, which were pre exposed to the optimum induction stress, exhibited better recovery growth. More importantly, though the induced and non induced seedlings are not different genetically, the induced seedlings showed higher tolerance by the enhanced expression of stress responsive genes. Joshi *et al.* (1997) also showed the genetic linkage between acquired thermo tolerance trait and the differential expression of a unique member of the HSP 26 gene family in wheat.

Thus, optimum lethal and induction temperatures were identified as 48°C for 2 hours; 35°Cfor 2 h followed by 40°C for 2 h and 45°C for one hour respectively using TIR technique for castor. Germplasm lines were screened to identify thermo tolerant lines using this technique. Highly tolerant lines to stress with >80% recovery with induction and <20% death even at lethal temperature are RG122, RG 226, RG 232, RG 235, RG 242, RG 247, RG 1096 and RG 1117.

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J. Oilseeds Res., **23**(2) : 356-357 (2006)

Short communication

Seed yield and net returns of rainfed castor, *Ricinus communis* L. as influenced by plant geometry and nitrogen levels*

C. Venugopal, G. Krishna Reddy and D. Srinivasulu Reddy

Department of Agronomy, S.V. Agricultural College, ANGRAU, Tirupati, AP

(Received: October, 2005; Revised: February, 2006; Accepted: June, 2006)

The productivity of castor in the state, Andhra Pradesh is quite low, because castor is grown on marginal and sub-marginal soils under rainfed conditions with low input use and poor crop management by the resource poor farmers. The biotic stress, i.e., capsule borer, semilooper and *Botrytis* also causes severe seed yield losses. As a consequence, cultivation of castor under rainfed conditions has become less remunerative.

Enhanced production is possible mainly through appropriate agro techniques such as genotypes sown at optimum time, maintaining optimum plant stand and judicious use of nutrients. The present study was, therefore, designed to obtain higher level of productivity of castor by selecting the suitable planting pattern and nitrogen doses for the southern agro-climatic zone of the Andhra Pradesh.

The experiment was conducted at dry land farm, S.V. Agricultural College, Tirupati during *kharif*, 2002. The experiment was laid out in the Randomized Block Design with factorial concept, replicated thrice, the treatments were comprising of four planting patterns. *viz.*, 90x20 cm, 60x30 cm , 45x40cm and 75x24cm and three nitrogen levels *viz.*, 40 kg/ha, 60 kg/ha and 80 kg/ha. The entire quantity of P_2O_5 (40 kg/ha) and half the quantity of N was applied as a basal dose. The remaining half of N was equally applied as top dress at 40 and 70 days after sowing.

The soil of the experimental field was sandy loam in texture having neutral pH with 223.7 kg/ha available N, 22.7 kg/ha available P and 315 kg/ha available potash. A total rainfall of 416.5 mm was received in 33 rainy days during the experimentation period (02.08.2002 to 25.01.2003). The gross plot size was 9.0 x 4.8 m.

Number of spikes/plant, number of capsules/spike and spike length was recorded on five randomly selected competitive plants. The capsule yield was recorded from 120 days after sowing to harvest as per the maturity and pooled yield was presented. Yield attributes, seed yield and net returns and their interaction were significantly influenced by planting pattern and nitrogen levels (Table 1 and 2).

Table 1 Yield attributes, seed yield and net returns of rainfed castor as influenced by plant geometry and nitrogen levels

Treatment	Spike length (cm)	No. of capsules/ spike	No. of spikes/ plant	Days to 50% flowering	Seed yield (kg/ha)	Net returns (Rs/ha)
Planting patterns (cm)						
P_1 x 90 x 20	26	43	5	53	18/51	17511
P_2 x 60 x 30	29	50	7	55	2083	20754
P_3 : 45 x 40	27	48	6	56	1932	18645
P_4 x 75 x 24	25	42	5	54	1720	15672
SEm±	0.3	0.3	0.01	0.3	16.3	246
CD (P=0.05)	0.9	1.0	0.04	1.0	48	718
Nitrogen levels (kg/ha)						
N_1 (40)	23.3	43.5	5.8	53.8	1777	16560
N_2 (60)	25.0	45.5	5.9	54.9	1907	18283
N_3 (80)	26.3	47.6	6.1	55.9	2007	19595
SEm±	0.2	0.3	0.0	0.3	13.2	284
CD (P=0.05)	0.8	0.9	0.04	0.9	39	829

* Part of M.Sc. (Ag.) Thesis submitted to the Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, AP.

Table 2 Interaction effects of plant geometry and N levels on yield attributes, seed yield and net returns of rainfed castor

Treatment	No. of capsules/ spike	No. of spikes/plant	Seed yield (kg/ha)	Net returns (Rs/ha)
$P_1 N_1$	38	5	1678	15184
$P_1 N_2$	44	5	1897	18150
$P_1 N_3$	47	6	1979	19199
$P_2 N_1$	49	6	1912	18460
$P_2 N_2$	50	7	2108	21104
$P_2 N_3$	51	7	2229	22699
$P_3 N_1$	47	6	1879	17998
$P_3 N_2$	48	6	1905	18262
$P_3 N_3$	49	6	2013	19675
$P_4 N_1$	41	5	1636	14596
$P_4 N_2$	41	5	1716	15616
$P_4 N_3$	43	5	1808	16805
SEm±	0.6	0.2	27.4	492
CD (P=0.05)	0.7	0.1	80	1436

The highest number of spikes/plant and the highest number of capsules/spike were recorded with the planting pattern of 60x30 cm, which was significantly superior to the other three planting patterns (Table 1). In crop geometry of 60 X 30cm, the branching pattern was better, which resulted in more number of branches resulting in the production of more number of spikes/plant. Spike production was found directly related to the number of branches (Hafeezuddin Khan, 1974). Number of spikes/plant and capsules/spike were found to be the highest with 80 kg N/ha, while 40 Kg N/ha recorded the lowest values for these traits. Better nutrition would have resulted in production of more number of spikes/plant and capsules/spike. Mathukia and Modhwadia (1993) also reported similar findings.

Days to 50% flowering were significantly influenced by different planting patterns. The planting pattern of 45 x 40 cm took more number of days to 50% flowering which was on par with planting pattern of 60 x 30 cm, but significantly superior to two other planting patterns. Castor crop flowered at the earliest with the planting pattern of 90 x 20 cm, which took significantly lesser number of days than under the planting pattern of 75 x 24 cm.

Nitrogen levels significantly influenced the days to 50% flowering. Among different nitrogen levels, 80 kg N/ha resulted in more number of days to attain 50% flowering and it was significantly longer than two low levels of N.

The lowest number of days to 50% flowering was recorded with application of 40 kg N/ha. Significant interaction effect with respect to days to 50% flowering between planting patterns and nitrogen levels was not traceable. The highest seed yield of castor was realized with the planting pattern of 60x30 cm, which was significantly superior to the remaining planting patterns tried, while the lowest seed yield was associated with planting pattern of 75x24 cm. Planting pattern of 60 x 30 cm has recorded 21% increase in the seed yield over 75 x 24 cm planting pattern. The higher seed yield under the planting pattern of 60x30 cm, seems to be the optimum spacing for obtaining higher yields due to more number of spikes/plant, capsules/spike, spike length and some other traits. The seed yield was also higher with the optimum spacing compared to deviated planting patterns. The highest seed yield of castor was produced with 80 Kg N/ha, which was however, significantly superior over the other two nitrogen levels. The lowest seed yield was recorded with the application of 40 kg N/ha. Application of nitrogen at 40 and 60 kg N/ha resulted in the decrease of seed yield by 11 and 5% respectively compared to 80 kg N/ha. Adequate nitrogen supply has promoted the growth and increased yield attributes such as number of spikes/plant and capsules/spike of castor resulted in the highest seed yield, as noticed in the present investigation confirms the findings of Hafeezuddin Khan (1974); Ganga Saran and Gajendragiri (1987). The highest net monetary returns of castor was recorded with planting pattern of 60 x 30 cm and nitrogen level of 80 kg/ha. The highest net returns of castor recorded with planting pattern of 60 x 30 cm, along with the application of 80 kg N/ha, this could be attributed to higher seed yield. The study revealed that growing rainfed castor with a planting geometry of 60x30 cm along with application of 80 kg N/ha was found economical for Southern-Zone of Andhra Pradesh.

The highest number of spikes/plant, capsules/spike, longest spikes, seed yield and net returns were recorded with the planting pattern of 60x30 cm with application of nitrogen at 80 kg/ha whereas they were lowest with planting pattern of 75x24 cm along with application of nitrogen at 40 kg/ha.

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J. Oilseeds Res., 23(2) : 358-360 (2006)

Short communication

Inheritance of rust resistance in groundnut, *Arachis hypogaea* L.

A. John Joel, P. Sumathi and T.S. Raveendran

Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore-641 003, TN

(Received: July, 2005; Revised: December, 2005; Accepted: December, 2005)

Leaf rust caused by *Puccinia arachidis* Speg. one of the major constraints in increasing the production of groundnut, which can affect up to 50% in susceptible cultivars. Though it can controlled by certain fungicides, economically it is not feasible for the small farmers in India. The cost benefit ratio and chemical hazards involved indicated that the most desirable approach would be to capitalize the genetic resistance. Development of resistance varieties require the knowledge on genetics and inheritance of the disease. Therefore, the present study was undertaken the genetics of rust resistance in groundnut.

Thirteen groundnut genotypes including five susceptible (CO 2, VRI 2, JL 24, TMV 2 and Girnar 1) and eight rust resistant (ALR 2, ICGV 86606, ICG 10030 A, ICG 10031, ICG 10052, ICG 10061, ICG 10939 and ICG 11285) were selected on the basis of their reaction to rust. These genotypes were crossed in line x tester matting design to obtain 40 hybrids. A total of 12 crosses *viz.*, CO 2 x ICG 10061, VRI 2 x ALR 2, VRI 2 x ICGV 86606, VRI 2 x ICG 10030 A, VRI 2 x ICG 10061, VRI 2 x ICG 10939, JL 24 x ICG 10031, JL 24 x ICG 10061, TMV 2 x ICGV 86606, TMV 2 x ICG 10052, Girnar 1 x ALR 2 and Girnar 1 x ICG 11285 were selected based on *per se* performance, *gca* and sca efforts for yield and associated traits. The six basic populations, *viz.*, P_1, P_2, F_1, BC_1, BC_2 and F_2 of these crosses were developed and grown in Randomized Block Design with three replications during *kharif*, 2001 at Agricultural Research Station, Bhavanisagar. The parents and F_1 of each cross were raised in single rows, BC_1 and BC_2 in three rows and F_2 in five rows. The observations on rust resistance were recorded on all the plants of different populations of all the twelve crosses. The chi-square test of goodness-of-fit was applied for the expected segregation ratios.

Under field conditions the F_1 plants of all the 12 crosses were susceptible showing that susceptible were dominant over resistance in these crosses (or) recessive with a dominant epistatic gene suppressing the effect of dominant gene. In F_2, three types of segregation for resistance and susceptibility were observed. The progenies segregated as three susceptible and one resistant in one cross; 15 susceptible and one resistant in 10 crosses and 63 susceptible and one resistant in one cross and confirmed susceptibility to be dominant (Table 1). The recessive nature of resistance is in accordance with the findings of Wynne *et al.* (1991) and Manoharan *et al.* (1994). In contrast to this Daisy Basandari *et al.* (2004) reported dominant nature of gene action for rust resistance. All the B_1 progenies (F_1 backcrossed to susceptible parent) were found susceptible and there was no segregation, as expected. However, segregation was noticed in B_2 crosses, which involved resistant parents and F_1s.

The F_2 population of the cross, TMV 2 x ICG 10052 segregated in the monogenic ratio of 3:1 for susceptible and resistant progenies and the test cross (B_2) had a segregation of one susceptible to one resistant plants confirming the monogenic inheritance. The same result was reported by Kaledhar *et al.* (1984). But Rahangdale and Raut (2004) reported that the single gene is responsible for resistance to rust with resistance being dominant over susceptibility.

In the F_2 population of the crosses, CO 2 x ICG 10061, VRI 2 x ALR 2, VRI 2 x ICGV 86606, VRI 2 x ICG 10030A, VRI 2 x ICG 10061, VRI 2 x ICG 10939, JL 24 x ICG 10030, JL 24 x ICG 10061, TMV 2 x ICGV 86606 and Girnar 1 x ICG 11285, a genetic segregation of 15:1 for susceptible and resistant plants were noticed. The B_2 population of these crosses fitted well into a 3:1 ratio of susceptible and resistance plants sowing that susceptibility was due to digenic duplicate epistatic genes (Manoharan *et al.*, 1994).

The F_2 population of these cross Girnar 1 x Alr 2 expected a trigenic segregation ratio of 63:1 for susceptibility and resistance. The test cross showed a genetic segregation of seven susceptible : one resistant plants for rust disease and confirmed the trigenic segregation observed in F_2 generation.

The present investigation revealed that rust resistant is governed by one (or) two (or) three recessive genes as evident from the segregation ratios of 3:1, 15:1 and 63:1 respectively, observed in the F_2 generation of the crosses under study .The segregation ratios in the two back crosses (B_1 and B_2) also supported the above finding. The recessive nature of resistance and dominant nature of susceptibility was also revealed.

Table 1 Reaction to rust resistance in six generations of 12 groundnut crosses

Crosse and generation	Observed number of plants			Genetic ratio (S:R)	χ^2 value	P value
	Susceptible (S)	Resistant (R)	Total			
			CO 2 x ICG 10061			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	297	20	317	15:1	0.0019	0.99-0.98
B_1	148	-	148	1:0	-	-
B_2	112	35	147	3:1	0.1110	0.80-0.70
P_2	-	60	60	NS		-
			VRI 2 x ALR 2			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	289	19	308	15:1	0.0034	0.95-0.90
B_1	139	-	139	1:0	-	-
B_2	116	37	153	3:1	0.545	0.90-0.80
P_2	-	60	60	NS	-	-
			VRI 2 x ICG 86606			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	291	20	311	15:1	0.0174	0.90-0.80
B_1	142	-	142	1:0	-	-
B_2	109	36	145	3:1	0.0023	0.99-0.98
P_2	-	60	60	NS	-	-
			VRI 2 x ICG 10030 A			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	284	18	302	15:1	0.0433	0.90-0.80
B_1	145	-	145	1:0	-	-
B_2	107	35	142	3:1	0.0093	0.95-0.90
P_2	-	60	60	NS	-	-
			VRI 2 x ICG 10061			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	291	19	310	15:1	0.0077	0.95-0.90
B_1	149	-	149	1:0	-	-
B_2	116	40	156	3:1	0.341	0.90-0.80
P_2	-	60	60	NS	-	-
			VRI 2 x ICG 10939			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	280	18	298	15:1	0.0224	0.90-0.80
B_1	148	-	148	1:0	-	-
B_2	114	37	151	3:1	0.0155	0.95-0.90
P_2	-	60	60	NS	-	-
			JL 24 x ICG 10031			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	287	19	306	15:1	0.0009	0.99-0.98
B_1	150	-	150	1:0	-	-

B_2	104	34	138	3:1	0.0096	0.95-0.90
P_2	-	60	60	NS	-	-
			JL 24 x ICG 10061			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	274	18	292	15:1	0.0036	0.98-0.95
B_1	144	-	144	1:0	-	-
B_2	111	35	146	3:1	0.0821	0.80-0.70
P_2	-	60	60	NS	-	-
			TMV 2 x ICGV 86606			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	279	19	298	15:1	0.0081	0.95-0.90
B_1	149	-	149	1:0	-	-
B_2	112	37	149	3:1	0.0023	0.98-0.95
P_2	-	60	60	NS	-	-
			Girnar 1 x ICG 11285			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	285	20	305	15:1	0.0492	0.90-0.80
B_1	142	-	142	1:0	-	-
B_2	105	36	141	3:1	0.00212	0.90-0.80
P_2	-	60	60	NS	-	-
			TMV 2 x ICG 10052			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	205	68	273	3:1	0.0012	0.99-0.98
B_1	145	-	145	1:0	-	-
B_2	73	75	148	1:1	0.0270	0.90-0.80
P_2	-	60	60	NS	-	-
			Girnar 1 x ALR 2			
P_1	60	-	60	NS	-	-
F_1	60	-	60	NS	-	-
F_2	301	5	306	63:1	0.102	0.90-0.80
B_1	146	-	146	1:0	-	-
B_2	136	20	156	7:1	0.146	0.90-0.80
P_2	-	60	60	NS	-	-

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J. Oilseeds Res., 23(2) : 361-362 (2006)

Short communication

Status on downy mildew, *Perenospora parasitica* and genetic variability for resistance in yellow sarson, *Brassica campestris* var. yellow *sarson*

R.B. Singh and Ram Bhajan[1]

Department of Genetics and Plant Breeding, N.D. University of Agril. & Tech., Kumarganj, Faizabad-224 229, UP

(Received: December, 2005; Revised: May, 2005; Accepted: June, 2005)

The oilseed crops especially *Brassica* species play a pivotal role in the agricultural economy of India. Among these *Brassica campestris* (var. yellow *sarson*) is an important *rabi* (post-rainy) crop of eastern India comprising Uttar Pradesh, Bihar, West Bengal and Assam. This crop together with *toria* (*B. campestris* var. *toria*) and Indian mustard [*Brassica juncea* (L.) Czern and Coss] is grown over an area of 6.75 m.ha with 1007 kg/ha productivity. But the rate of yield and hectarage is highly imbalanced. A major contributor to the low productivity are foliar diseases, particularly *Alternaria* blight, white rust and downy mildew (Singh and Bhajan, 2005; Singh and Singh, 2005a). Downy mildew caused by *Perenospora parasitica* affects these crops in seedling/vegetative stage. Published information on this disease from eastern India in respect of yellow *sarson* appears to be scanty. Therefore, investigations were undertaken to study its occurrence, severity and varietal resistance.

Survey was carried out in yellow *sarson* growing zone of eastern Uttar Pradesh during October, November, December and January at 15-day intervals. Infected samples of cotyledons, leaves, inflorescence and siliquae at different stages of crop growth were collected separately from farmers' fields and experimental plots. Causal fungi were isolated and its pathogenicity was tested as per Abd-Elrazik and Lorbeer (1980). Disease incidence intensity, days to highest disease severity from first appearance and mean per cent disease intensity (PDI) over the years were recorded (Table 1). Approximately date of sowing was also recorded from respective farmers. Disease severity was recorded using scale given by Natti *et al.* (1967) and PDI was calculated.

Eighty-three yellow *sarson* genotypes comprising 65 collections from different parts of eastern Uttar Pradesh (NDYS-series) and 18 lines (YSC-series) procured from ARS, Bawal (Haryana) were evaluated for their response to downy mildew during 2002-03 and 2003-04 crop season in plot having supplementation of diseased plant debris from preceding four seasons. The trial was sown in second fortnight of September in single row of 3 m having 30 cm x 10 cm spacing in Randomized Block Design with two replications. Susceptible cultivar YST-151 was sown after every 5-test genotypes and was also flanked all around the trial by paired rows to serve as infector. Based on scale and disease intensity the genotypes were grouped into resistant/susceptible.

Downy mildew happened to be of regular occurrence on yellow *sarson* in the areas surveyed in eastern Uttar Pradesh and showed variety of symptoms individually and in mixed infection (in late sown crop only) as reported earlier from the state of North-Western (Kolte, 1985; Saharan *et al.*, 1997) in mid-eastern India (Singh and Singh, 2005b) in mustard. Fungus isolated was found pathogenic and producing typical downy mildew symptoms on vegetative parts was *Perenospora parasitica* (Press-ex Fr.) Fr. as reported by Saharan *et al.* (1997).

Observations recorded for 10 consecutive crop seasons (1995-96 to 2004-05) established *P. parasitica* as the causal agent of downy mildew. Initial symptoms could be noted as early as on 12th October attaining the highest PDI 85.8 on 2nd December, 1999 and as late as on 25th November attaining highest PDI of 45.0 on 10th December in 2003. Highest PDI ranged between 35.3 (1998-99) to 85.8 (1999-2000). The highest PDI of 75.5 was recorded in 1995-96, and then there was a constant decline upto 35.3 (1998-99) and again it reached maximum up to 85.8 in 1999-2000) when sowing was done earlier in the second fortnight of September. Downy mildew pressure was higher during 2000-01 to 2003-04 (70.3 to 80.8) when the crops were sown in first fortnight of October. In 2004-05, reduced PDI was noted (45.0) when the crop was sown in the second fortnight of November. It clearly indicates that early sowing is more prone to downy mildew disease at cotyledonary/leaf stage infection than late sown crop. Early sown crop during September took more time (40 days) for attaining the highest disease severity. As the date of sowing was delayed, the time for attaining the highest severity decreased. Minimum time of 15 days was

[1] Department of Genetics and Plant Breeding, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttaranchal.

taken to attain the highest severity of disease 45% in the crop sown on 9th November, 2004. It clearly indicates that the early sown crop gets more exposure to inoculum and congenial weather conditions such as air temperature, relative humidity and residual soil moisture, which favour the disease development, than in late sown crop. Information on these lines on yellow *sarson*, in this region, has been gathered for the first time. Downy mildew, however, is noted to appear first by the end of October and progress upto November on mustard in North-Western India also and variation of severity in different years appear to be associated with environmental variables such as temperature variation, humidity, rainfall and sunshine hours (Saharan, 1992; Sahran *et al.*, 1997).

Table 1 Occurrence and severity of downy mildew of yellow *sarson* over the year in eastern Uttar Pradesh

Year	Date of sowing	Date of first appearance	Highest disease intensity (%)	Date of highest disease intensity attained	Days to highest disease intensity attained from first appearance
1995-96	22nd October, 1995	11th November, 1995	75.5	2nd December, 1995	21
1996-97	18th October, 1996	7th November, 1996	65.5	28th November, 1996	21
1997-98	20th October, 1997	7th November, 1997	45.7	24th November, 1997	17
1998-99	16th October, 1998	4th November, 1998	54.7	20th November, 1998	16
1999-2000	20th September, 1999	12th October, 1999	35.3	2nd December, 1999	40
2001-01	14th October, 2000	30th October, 20000	85.8	24th November, 2000	24
2001-02	8th October, 2001	22nd October, 2001	70.3	20th November, 2001	28
2002-03	3rd October, 2002	14th October, 2002	80.8	24th November, 2002	40
2003-04	15th October, 2003	26th October, 2003	75.6	20th November, 2003	24
2004-05	9th November, 2004	25th November, 2004	45.0	10th December, 2004	15

None of the germplasm lines was free from this disease, while 11 lines *viz.*, NDYS-2, NDYS-8, NDYS-121, NDYS-132, NDYS-135, NDYS-136, NDYS-139, NDYS-140, YSC-4-1, YSC-5 and YSC-24-1 were recorded resistant and 15 lines, *viz.*, NDYS-4, NDYS-4-4, NDYS-5-2, NDYS-71-, NDYS-116, NDYS-177, NDYS-122, NDYS-134, NDYS-138, NDYS-141, YSC-4, YSC-7-1, YSC-4-29, YSC-31-1 and YSC-84 as moderately resistant. Besides these, 22 genotypes were rated as moderately susceptible, 19 susceptible and one as highly susceptible. Earlier literature (Kolte, 1985; Saharan, 1992; Saharan *et al.*, 1997; Singh and Singh, 2005b) also reported a number of genotypes resistant to individual diseases in rapeseed-mustard, all from North-Western India.

Acknoweldgement: Authors are thankful to Director of Research, N.D. University of Agriculture and Technology for providing the necessary facilities and to ICAR for financial assistance.

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J. Oilseeds Res., **23**(2) : **363 (2006)**

Short communication

Yield losses due to bud fly, *Dasyneura lini* Barnes in linseed

Y.P. Malik

PC & GM Unit (Linseed) C.S. Azad University of Agriculture and Technology, Kanpur-208 002, UP

(Received: February, 2005; Revised: August, 2005; Accepted: September, 2005)

Bud fly (*Dasyneura lini* Barnes) is one of the limiting factors in linseed production, which causes enormous avoidable yield losses particularly in the central and northern India. Information on the extent of yield losses due to this pest in different parts of the affected region is lacking. Thus, it is imperative to specify the losses in linseed due to bud fly in India.

Uniform pest nursery trials (UPN) for bud fly resistance in linseed were conducted for thirteen years (1990-91 to 2003-04) at fourteen locations of central and northern parts of the country comprising ten states *viz.*, Himachal Pradesh, Haryana, Uttar Pradesh, Bihar/Jharkhand, West Bengal, Orissa, Madhya Pradesh, Chhattisgarh, Maharashtra and Rajasthan. The year-wise highest degree of bud fly infestation on any entry of linseed in UPN at test locations was taken into consideration, as the quantum of bud fly infestation is the direct loss in seed yield of linseed (Malik, 2000). The lowest and highest degree of bud infestation at a particular place over years was considered as the range of yield loss, while the simple mean over years and weighted mean over locations were calculated to achieve the average loss for a location and state, respectively. National average loss was computed based on weighted mean of all locations over years.

UPN trials conducted in Himachal Pradesh (Kangra), Haryana (Hisar), Uttar Pradesh (Kanpur, Faizabad and Mauranipur), Bihar/Jharkhand (Kanke), West Bengal (Berhampore), Orissa (Chiplima and Jashipur), Madhya Pradesh (Tikamgarh and Rewa), Chhattisgarh (Raipur), Maharashtra (Nagpur) and Rajasthan (Kota) revealed a great variation in yield losses due to bud fly in linseed ranging up to 6% at Jashipur to 17-89% at Nagpur. Average yield losses in chronological order at different locations were calculated to be 6, 17, 23, 26, 43, 45, 47, 49, 53, 55 and 57% at Jashipur, Kota, Hisar and Berhampore, Kangra and Faizabad, Tikamgarh, Raipur, Kanpur and Kanke, Nagpur, Rewa, Chiplima, and Mauranipur locations, respectively, while yield losses at state level on weighted mean basis over locations were 17, 23, 26, 38, 43, 45, 47 and 49% in Rajasthan, Haryana and West Bengal, Himachal Pradesh, Orissa, Uttar Pradesh, Madhya Pradesh and Chhattisgarh, Bihar/Jharkhand, and Maharashtra, respectively. At national level, the yield losses varied between 17-49% with an average of 40%. It can be concluded that minimum yield loss in linseed due to bud fly on location basis were up to 6% at Jashipur (Orissa) against maximum of 17-89% at Nagpur (Maharashtra), while on state basis Rajasthan faced minimum yield losses (17%) against the maximum (49%) in Maharashtra. Yield loss at national level estimated to be 40%. The extent of losses in linseed due to bud fly up to 50% at Pusa in Bihar, 15-39% in Madhya Pradesh and up to 69% at Kanpur in Uttar Pradesh (Malik, 1999 and Malik *et al.*, 2001) confirm these findings.

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J. Oilseeds Res., **23**(2) : 364-365 (2006)

Short communication

Effects of micronutrients on nodulation, N_2-fixation and yield of soybean, *Glycine max* (L.) Merrill in lateritic acid soil of West Bengal

S.K. Mondal and S.C. Poi

Dept. of Agril. Chemistry and Soil Science, Bidhan Chandra Krishi Vidyapeeth, Mohanpur-741 252, Noida, WB

(Received: May, 2003; Revised: September, 2004; Accepted: June, 2006)

During the past few decades numerous reports had been made that various trace elements influenced the symbiotic N_2-fixation in legumes. The molybdenum (Mo) and iron (Fe) had been found to be the most important micronutrient in this regard as it is an essential component of one of the two proteins which togetherly constituted the N_2 fixing enzyme complex "nitrogenase" (Burris, 1969). A few other elements like Mn, B, Zn and Co also reported to influence the symbiotic N_2-fixation somehow or other. Kabi and Poi (1980) found nodulation and N_2-fixation were effective in *Glycine max* while Mo and B were applied.

A single variety of soybean cv. Bragg was incoulated with a single strain of *Brandyrhizobium japonicum* (S_2) in lateritic acid soil of West Bengal in Raghunathpur Farm, BCKV both under pot and field conditions in the year, 2000 and 2001 and date of sowing was 4th week of July in every year and date of harvesting was end of October to 1st week of November. The plot size was 2 m x 2 m. Seed rate was 50 kg/ha, spacing was 30 cm between row and 10 cm plant to plant. The experiment were designed in Randomised Block Design with four replications keeping the basal doses of N_{30} P_{60} K_{40} and micronutrient : Zn, Fe, B, Mo and mixed (all the micronutrients at a time) @ 2 ppm/pot and @ 1 kg/ha in field as their salts. The strain (S_2) incoulated seeds were used in all the treatments both in pots and field. After 60 days, plants were taken out without damaging the root system both from pot and field and data on nodulation were recorded. The plants dry weight were recorded from oven dried plants and nitrogen and phosphate contents were estimated by Jackson (1962) method from oven dried sample. The grain yield was recorded after harvesting the crop. Soil pH : 5.51; organic C (%) : 0.650; total N (%) : 0.123; available N (kg/ha) : 240.2; P_2O_5 (kg/ha) : 13.86; K_2O (kg/ha) : 215.6 were analysed following the method of Jackson (1962). Available micronutrients were estimated by Atomic Absorption Spectrophotometer (Perkin Elmer, Model 2380).

Table 1 Available micronutrients in the soil micronutrients (ppm)

Soybean required	Zn	Fe	B	Mn	Mo	Cu	CD at 5% level
	21-50	51-350	21-55	21-100	0.11-180	10-30	
Acid soil	4.3	43.3	2.3	4.3	0.08	5.0	1.5

Addition of Zn, Fe, Mo, B and mixed micronutrients increased the nodulation, plant fresh and dry weight (g)/plant, total N (%), P (%), grain yield (kg/ha) over the control both in pot and field condition (Table 2).

Table 2 Effect of micronutrients on symbiotic performance of *B. Japonicum* strains (S2) and soybean (cv. Bragg) both in pot and field with acid soils

Micronutrient	Nodule number/plant		Nodule fresh wt. (g)/plant		Plant fresh weight (g)/plant		Plant dry weight (g)/plant		Seed weight (kg/ha)	Yield increased over control	Total N (%) in plant		Total P (%) in plant	
	Pot	Field	Pot	Field	Pot	Field	Pot	Field			Pot	Field	Pot	Field
Control	10	25	0.131	0.533	1.180	55.824	0.248	5.468	1091	-	2.5	3.216	0.4	0.3
Zn	12	26	0.245	0.915	1.793	63.143	0.317	7.014	1313	20.3	2.8	3.492	0.4	0.4
Fe	16	26	0.183	0.895	1.653	60.375	0.315	6.133	1093	0.1	2.7	3.325	0.4	0.4
B	16	28	0.285	1.191	2.187	66.033	0.421	7.529	1416	29.7	3.1	3.333	0.4	0.4
Mo	11	27	0.295	1.270	2.343	68.130	0.503	8.036	1596	46.2	3.3	4.012	0.4	0.4
Mixed	14	31	0.367	1.345	2.473	72.143	0.518	8.567	1606	47.1	3.3	4.120	0.4	0.4
CD (P≥0.05)	0.754	0.6	NS	0.30	0.2	2.532	NS	0.1	15.5	-	0.0	0.009	0.0	0.0

Here it was also found that the Mo and B were most effective in increasing nodulation, N_2-fixation and grain yield. But, mixed treatment showed the highest N % and 47.17 % increment yield. Kabi and Poi (1980) found nodulation and N_2-fixation were increased by Mo and B application. Posypanov and Zherkov (1992) also found the same result.

It was found in the present study that Fe, Mo and B significantly increased the nodule number, nodule fresh weight and N uptake in plant over the inoculated control. It was also found that Mo had maximum influenced on nodulation and N uptake in soybean in both pot culture and field condition in acid soil. But, when all micronutrients were taken at a time (mixed) this was found to be more effective than Mo alone. The grain yield was highest when mixed micronutrients applied to the soil.

As the soil was deficient (Table 1) of Mo and B, the supplementation with these micronutrients probably influenced the plant growth and yield of soybean in acid soil.

From the above text it may be concluded that the judicial application of micronutrients was needed for cultivation of soybean in lateritic acid soils for better yield of soybean.

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J. Oilseeds Res., **23**(2) : 366-371 (2006)

Short communication

Influence of fertility-salinity interaction on mineral composition in *Brassica juncea* L.

Rajiv Kumar[1] and M.S. Kuhad

Department of Botany and Plant Physiology, College of Basic Sciences and Humanities, CCS Haryana Agricultural University, Hisar-125 004, Haryana

(Received: April, 2005; Revised: April, 2006; Accepted: June, 2006)

Rapeseed and mustard are the important oilseeds grown in arid and semi-arid regions, which are generally, affected either by salinity of soil or irrigation water. In saline environment, salt ions competitively reduce the uptake of nutrients thus plants face situation of deprivation of essential nutrients. Changes in growth of plants under salinity appears to be associated with reduced absorption of essential nutrient elements or high electrolyte levels contributing toward osmotic adjustment and salt tolerance and ion toxicity (Greenway and Munns, 1980). One of the major approaches to control the salinity syndrome in surface soil has been to leach down soluble salts from soil profile by excess irrigation with good quality water. But this practice is no longer acceptable because of limited water resources. One of the cost effective strategies for combating salinity involves growing plants that have inherent ability to withstand saline environment (Steppuhn *et al.*, 1991). But owing to excessive spatial and temporal variation in salt concentration particularly under arid conditions, this attempt is relatively unsuccessful (Holm, 1983). For the last few decades, major area of emphasis has been to exploit the favorable ionic interactions in growth medium to mitigate the salinity hazards. Keeping this in view the present study was conducted.

An experiment was conducted during November 2001 in sand culture in screen house of College of Basic Sciences and Humanities, Chaudhary Charan Singh Haryana Agricultural University, Hisar. Mustard (cv. RH-30) was raised in cemented pots, each of which was filled with 6 kg of dune sand. Some of the physico-Chemical characteristics of experimental dune sand were given in Table1.

Ten seeds were sown in each pot and pots were supplied with phosphorus and sulphur alone and in combinations in different concentrations. Each pot was supplied with equal quantity of nutrient solution (Hoagland's) at a regular interval of 15 days. The desired salinity levels (ECe 0, 8 and 12 dS/m) were obtained by adding Cl and SO_4 salts of Na, Ca and Mg [Na: (Ca+ Mg) =1:1, Ca: Mg = 1:3, Cl: SO_4= 7:3 on meq basis]. Non-saline control was kept. Saline irrigation was given at 55 days after sowing (DAS) and sampling was done ten days after treatment. Phosphorus (KH_2PO_4): 20, 40 and 60 kg/ha, Sulphur (K_2SO_4): 10, 20 and 30 kg/ha, Combinations (KH_2PO_4 + K_2SO_4): 20+10, 40+20, 60+30 kg/ha were given after emergence. Additional amount of K was compensated in control with the addition of KCl. Minerals like nitrogen, phosphorus, sodium, calcium, magnesium, chloride and sulphate were determined from the oven-dried leaves. Except for chloride, the extraction/ digestion procedure was common for all other elements (USDA Hand book, 1960). For sulphate extraction concentrated HNO_3 was used instead of H_2SO_4. Data on nitrogen (Kjeldahl's steam distillation method AOAC, 1975), phosphorus (Jackson 1973), potassium and sodium (flame photometer Elico, India), Calcium and Magnesium (USDA, Handbook, 1960), Chloride (Ramsay *et al.*, 1955) and Sulphate (Verma, 1977) were recorded.

Table 1 Physico-chemical properties of dune sand used for experiment

Property	Type
Mechanical analysis	Sand (93.3%); Silt (3.0%); Clay (3.7%)
Texture	Sand
Saturation capacity	25%
pH	8.2
Ece	0.8 dS/m at 25°C
$CaCO_3$	Absent
Organic carbon	0.06%
CEC	2.56 Cmol (+)/kg
Available nutrients (ppm)	N (10.3), P (2.5), K (18.0)
Taxonomic class	Typic torrispamments

[1] Central Institute for Cotton Research, Regional Station, Sirsa-125 005, Haryana.

Salinity caused significant reduction in nitrogen, phosphorus, potassium, magnesium along with increase in calcium content over non-saline plants (Fig. 1 & 2). Earlier reports also indicated that salinity reduces N accumulation in the plants (Feigin, 1985; Garg *et al.*, 1993). Increased phosphorus concentration, increased nitrogen, phosphorus, potassium, magnesium and calcium under saline condition. Likewise, sulphur also increased nitrogen, phosphorus and potassium content of leaves except at 30 kg/ha where reduction in nitrogen, phosphorus and potassium content was observed. Sulphur application also increased calcium content. However, combination of two fertilizers improved nitrogen, phosphorus, potassium and magnesium content of leaves and the response was better as seen in case of individual fertilizer treatments. With the increase in salinity upto 12 dS/m the cation/anion ratio decreased significantly, which showed dominance of anion uptake. With increased salinity, Na content increased with a corresponding decline in K content. Many studies have shown that K concentration in plant tissues get reduced as Na salinity or Na/Ca ratio in root media increased (Subbarao *et al.*, 1990). Reduction in K uptake in plants by Na is a competitive process and occurs regardless of whether the solution is dominated by Na salt of Cl or SO_4. In most of the studies, Na salt decreased drymatter production and K content of leaf as well as its uptake (Garg and Garg, 1980). In the present study, the gradual decrease in K with salinity in leaves was accompanied with more Na uptake and thus consequently decrease K /Na ratio. The increase in level of Na and decrease in K was also reported in cotton (Rathert, 1983). Subsequent studies by Hu and Schmidhalter (1988) revealed that Na and Cl concentration increased under salinity and were more in the elongated leaves of wheat. Sodium, chloride and sulphate increased significantly under saline conditions (Fig. 3). Treatment with phosphorus decreased the sodium content under salinity upto its highest level (30 kg/ha). Sulphur reduced the chloride content of leaves under salinity but reverse was the case at highest sulphur level (30 kg/ha) where increase was noticed while further increase in sulphate with Sulphur application. The increase Cl concentration under salinity was observed in Brassica (He and Cramer, 1993). Fertilizer -induced salt tolerance may possibly be achieved of Na, Cl and SO_4 in leaves. However, highest increase in higher sulphate and chloride with higher level of sulphur under salinity may be due to its action synergistically with salinity and shows positive Cl:SO_4 interactions when applied alone. However, when S applied in combination of P under salinity the effect was beneficial. This might be due to the preferential uptake of phosphate over sulphate thus avoiding excess uptake of sulphate. The response of the phosphorus and sulphur on uptake of different elements in different crops under saline irrigation was reported by several workers like increased phosphorus level increased p uptake under saline irrigation in brassica (Kumar *et al.*, 2005), increase in K content of chickpea by using sulphur in saline-soils (Hari Ram and Dwivedi, 1992), decreased Ca with increase in Mg absorption with P application. The increase in Mg content of leaf with increasing P level may be attributed in yield of crop resulting in high biomass to absorb plant nutrients more effectively. Malakondaiah and Rajeshwearарao (1979) observed a decrease in Na content of groundnut in saline soil with the application of phosphorus and reduction of sodium content in sunflower with sulphur was observed by Malik (1994). Phosphorus at all the levels of salinity depressed the chloride content significantly. The reason for reduced chloride content in plant parts may be due to the fact that trivalent phosphate ion is more effective in absorption than monovalent chloride ion. Such mutual antagonism has already been reported earlier by Malik (1994).

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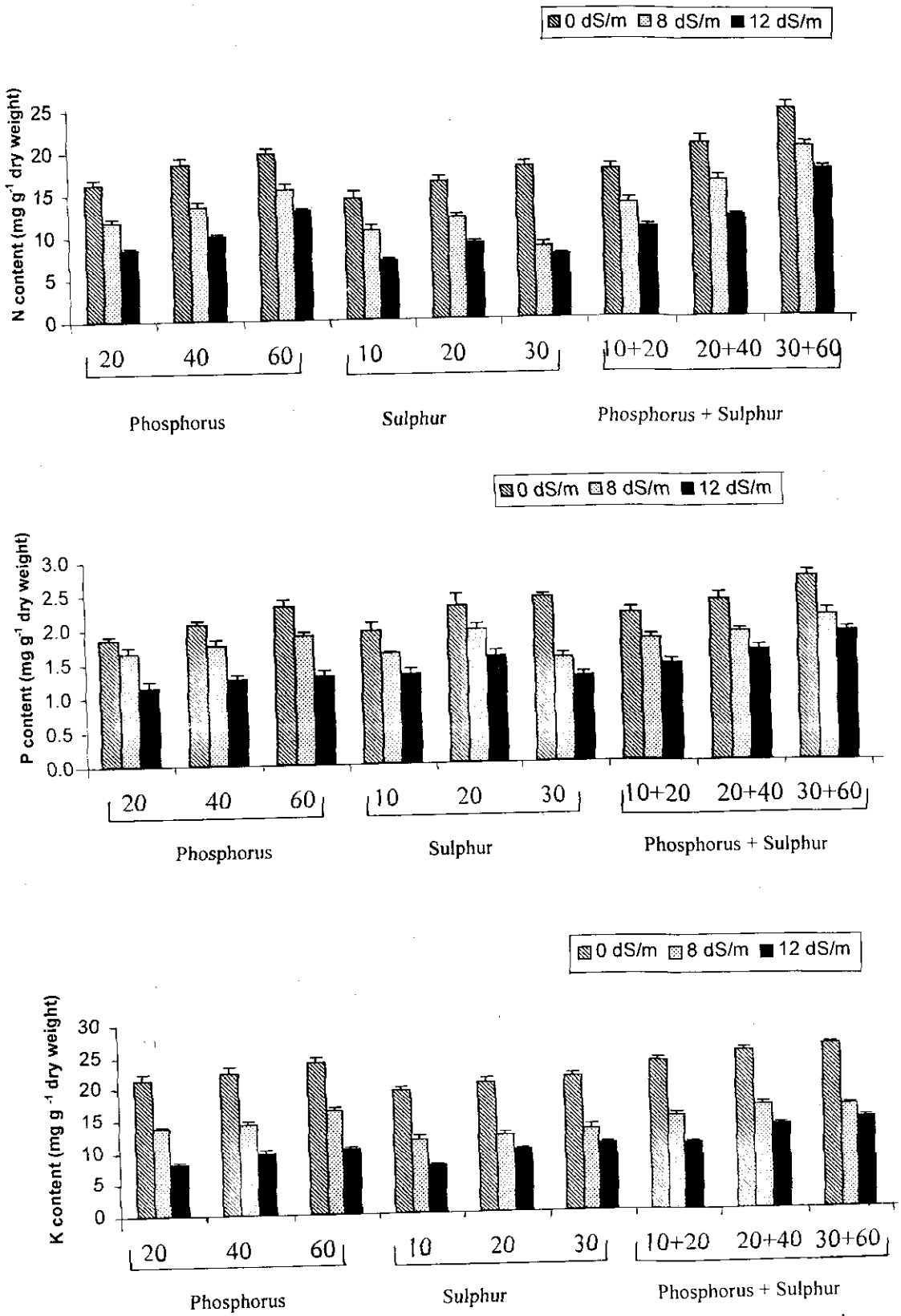
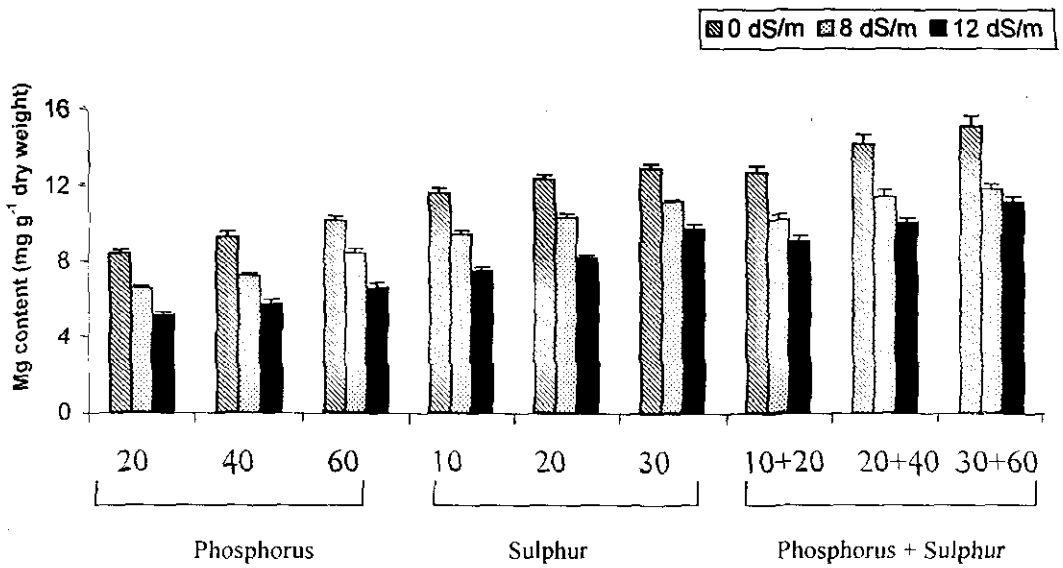


Fig.:1 Effect of phosphorus, sulphur and their interaction with salinity on nitrogen, phosphorus and potassium content in *Brassica juncea* L.



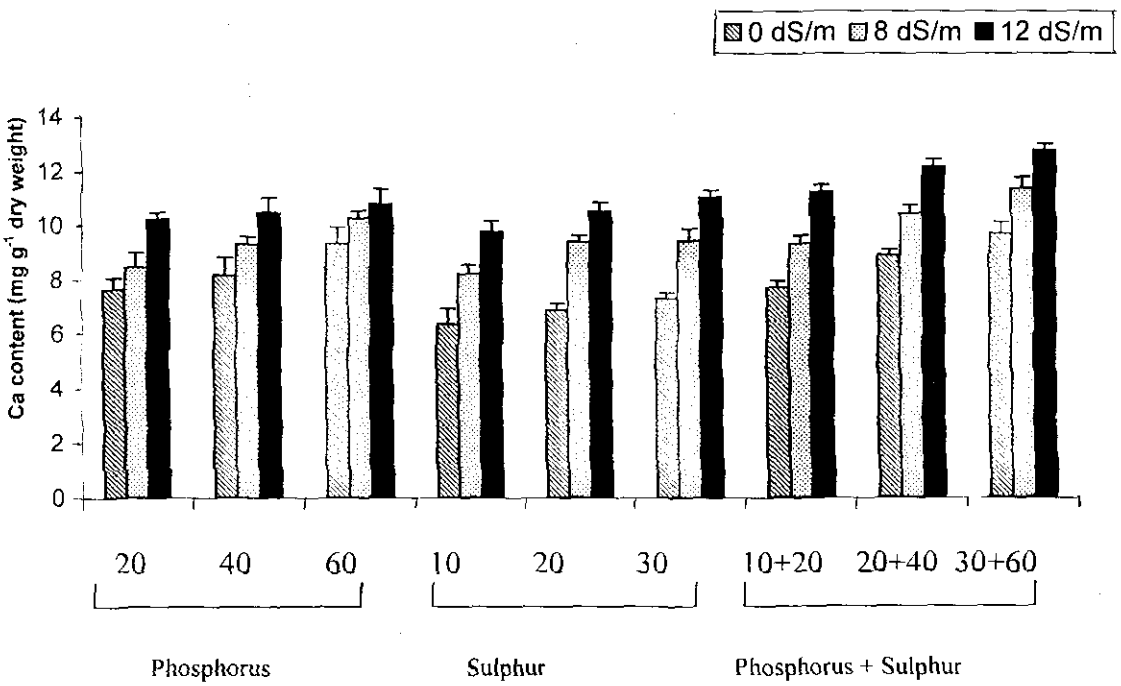


Fig.:2 Effect of phosphorus, sulphur and their interaction with salinity on magnesium and calcium content in *Brassica juncea* L.

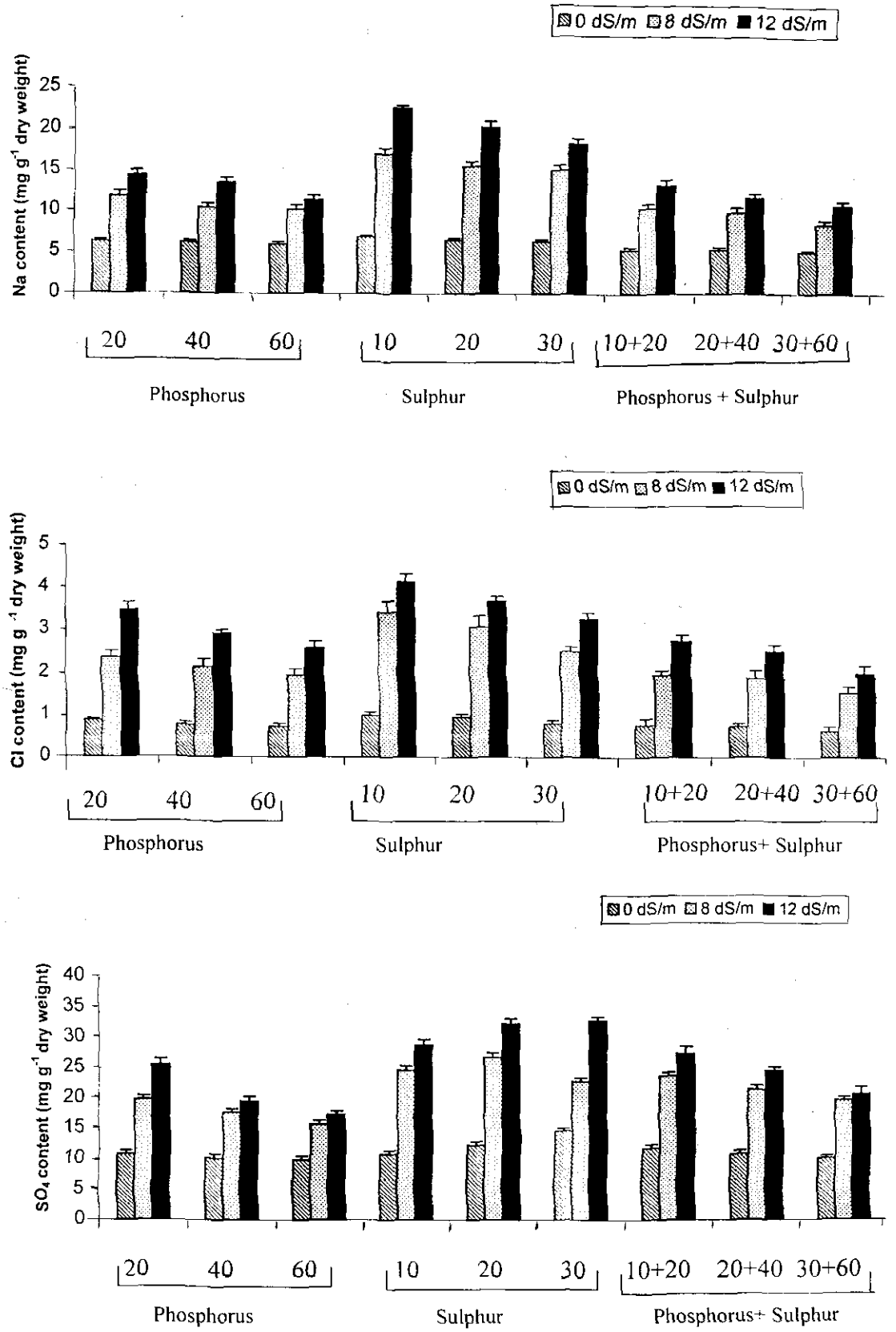


Fig.:3 Effect of phosphorus, sulphur and their interaction with salinity on sodium, chloride and sulphate content in *Brassica juncea* L.

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J. Oilseeds Res., **23**(2) : **372-373 (2006)**

Short communication

Screening of sunflower, *Helianthus annuus* L. genotypes by temperature induction response (TIR) technique

B. Srinivas, Kuldeep Singh Dangi, Laxmi Prayaga[1] and S. Sudheer Kumar

Department of Genetics and Plant Breeding, College of Agril., ANGRAU, Rajendranagar, **Hyderabad-500 030, AP**

(Received: October, 2004; Revised: March, 2006; Accepted: June, 2006)

High temperature is one of the important environmental factors affecting crop productivity. Temperature higher than the optimum decrease both the rate and duration of metabolic processes and thus decrease the yield. It has been shown in crops including wheat that for every one degree rise of temperature over the range of 12.2-27.5°C the yield is reduced by 4% (Howard, 1924). Therefore, to sustain the agricultural production it is necessary to breed varieties which are tolerant to high temperature stress.

Plants when exposed to sub-lethal stress (induction stress), develop the ability to withstand severe temperatures and this phenomenon is often referred to as acquired thermotolerance. Earlier it was reported that stress alters gene expression and brings greater adaptation to heat stress and that the genetic variability in thermotolerance is only seen upon induction stress. In the present study, the application of the temperature induction response (TIR) technique (Kumar *et al.*, 1999) for identifying highly thermotolerant lines from open pollinated populations of sunflower was studied.

A laboratory study was conducted at Directorate of Oilseeds Research, Rajendranagar, Hyderabad with a set of 100 sunflower germplasm monitoring unit (GMU) lines serially numbered GMU-101 to GMU-200 to assess their thermotolerance by using temperature induction response (TIR) technique. The pre-imbibed seeds were germinated on moist filter paper in petridishes at 30°C and the uniform seedlings of 1 to 1.5 cm in length were transferred @ 20 per petridish to three different sets *viz.*, control, induction and lethal treatment for each genotype and two replications were maintained for each set. One set of seedlings were subjected to gradual induction (at 35°C for 2 hrs, 40°C for 1 hr and 45°C for 1 hr) treatment and other two sets were maintained at room temperature (non induced). The induced and one set of non-induced seedlings were transferred to lethal temperature at 52.5°C for 1 hr (which causes the 80% mortality). The other set of non-induced seedlings were kept as absolute control. Finally the seedlings in all three sets were allowed to recover at 30°C for 72 hrs and per cent survival at the end of 72 h was recorded.

The results of the study revealed that the seedlings which were exposed to the induction temperature (at 35°C for 2 hrs, 40°C for 1 hr and 45°C for 1 hr) prior to lethal temperature exposure (52.5°C for 1 hr) exhibited seedling survival during the recovery period, while the seedlings, exposed directly to lethal temperature (52.5°C for 1 hr) had zero survival during recovery period. Nel (1998) obtained similar results by studying thermotolerance of sunflower genotypes. He observed the hypocotyls of seed pre-exposed were shorter than untreated seed, indicating the inability to acquire thermotolerance. Srikanthbabu *et al.* (2000) studied pea genotypes and found that, pea seedlings exposed to induction temperature prior to lethal temperature showed higher recovery growth compared to seedlings which were directly exposed to lethal temperature.

Among the one hundred lines studied, eleven genotypes *viz.*, GMU-109, GMU-129, GMU-133, GMU-134, GMU-138, GMU-141, GMU-149, GMU-157, GMU-175, GMU-185 and GMU-196 exhibited above 80 per cent seedling survival during recovery period were considered as thermo tolerant (Table-1). Out of these eleven thermotolerant lines identified, one line GMU-157 exhibited highest per cent (93.5) seedling survival. The line GMU-157 was the only line which showed 25% seedling survival when exposed directly to lethal temperature at the end of the recovery period. Besides the line GMU-157 the other genotypes, GMU-175 (87.5%), GMU-149 (87.0%), GMU-133 (84.7%), GMU-138 (84.5%), GMU-196 (84.5%), GMU-141 (83.5%), GMU-129 (83.0%), GMU-185 (82.5%), GMU-109 (82.2%) and GMU-134 (81.5%), also appeared to be desirable for thermotolerance.

These lines can be exploited in breeding programmes for identification of thermotolerant hybrids since, the hybrids developed from selected variants of parental lines for thermotolerance are expected to be more tolerant compared with the original hybrid (Senthil Kumar *et al.*, 2003).

[1] Senior Scientist (Plant Physiology), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, AP.

Table 1 Per cent seedling survival after recovery period in control induced and lethal temperature treatments

GMU line	Survival (%) (IT)	GMU line	Survival (%) (IT)	GMU line	Survival (%) (IT)	GMU line	Survival (%) (IT)
GMU-101	75.0	GMU-126	55.0	GMU-151	33.0	GMU-176	60.0
GMU-102	71.2	GMU-127	32.5	GMU-152	32.5	GMU-177	65.0
GMU-103	75.0	GMU-128	67.5	GMU-153	30.0	GMU-178	20.0
GMU-104	65.0	GMU-129	83.0	GMU-154	35.0	GMU-179	25.0
GMU-105	55.0	GMU-130	60.0	GMU-155	10.0	GMU-180	45.0
GMU-106	75.0	GMU-131	72.5	GMU-156	40.0	GMU-181	70.0
GMU-107	70.0	GMU-132	64.5	GMU-157	93.5	GMU-182	17.5
GMU-108	70.0	GMU-133	84.7	GMU-158	72.5	GMU-183	15.0
GMU-109	82.2	GMU-134	81.5	GMU-159	15.0	GMU-184	32.5
GMU-110	60.0	GMU-135	77.5	GMU-160	25.0	GMU-185	82.5
GMU-111	55.0	GMU-136	70.0	GMU-161	40.0	GMU-186	35.0
GMU-112	50.0	GMU-137	72.5	GMU-162	65.0	GMU-187	24.5
GMU-113	65.0	GMU-138	84.5	GMU-163	50.0	GMU-188	30.0
GMU-114	65.0	GMU-139	22.5	GMU-164	32.5	GMU-189	22.5
GMU-115	72.5	GMU-140	72.5	GMU-165	55.0	GMU-190	16.5
GMU-116	57.5	GMU-141	83.5	GMU-166	52.5	GMU-191	5.0
GMU-117	75.5	GMU-142	77.5	GMU-167	42.5	GMU-192	75.0
GMU-118	67.5	GMU-143	15.0	GMU-168	55.0	GMU-193	55.0
GMU-119	55.5	GMU-144	12.5	GMU-169	35.0	GMU-194	36.3
GMU-120	78.5	GMU-145	67.5	GMU-170	20.0	GMU-195	23.1
GMU-121	60.0	GMU-146	27.5	GMU-171	20.0	GMU-196	84.5
GMU-122	67.5	GMU-147	30.0	GMU-172	27.5	GMU-197	50.0
GMU-123	52.7	GMU-148	32.5	GMU-173	7.5	GMU-198	10.0
GMU-124	47.5	GMU-149	87.0	GMU-174	87.5	GMU-199	10.0
GMU-125	17.5	GMU-150	37.5	GMU-175	60.0	GMU-200	47.5

IT = Induction treatment

Per cent survival in control was **100%**, while under lethal temperature stress was 0% (except for GMU-157) for all the genotypes. Hence, data for induced treatment only are furnished.

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J. Oilseeds Res., 23(2) : 374-376 (2006)

Short communication

Estimation of optimum size and shape of plot for field experiments on irrigated castor, *Ricinus communis* L.

J.K. Patel, G.K. Chaudhary, K.S. Patel and J.M. Loria

C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar-385 506, Gujarat

(Received: March, 2005; Revised: August, 2005; Accepted: September, 2005)

Gujarat shares about 43% of the total area and 74% of the total castor production of the country (Damodaram and Hedge, 2002). Considering the importance of the crop in the state and the role of optimum size and shape of the plot in minimising experimental error, an uniformity trial was conducted to determine the optimum size and shape of the plot on irrigated castor during the *kharif*, 2003-04 at the Main Castor Research Station, S.D. Agricultural University, Sardarkrushinagar, Gujarat. Castor variety, GCH-4 was planted with 90 cm, distance between rows and 60 cm between dibbles within row. The rainfall during the crop growth period was 311 mm in 17 rainy days. Seven irrigations were given during the crop season. Since, castor is a space planted crop, the individual plant (0.54 m^2) was considered as basic unit (Federer, 1955). The whole uniformity trial was marked into four blocks each of 20 rows having 20 plants in each row. Thus, there were 400 plants (basic units) per block and in all 1600 plants under experiment. The area harvested excluding the borders were 40 x 40 basic units (i.e., 40 m x 24 m = 960 m^2). The seed yield of individual plant (basic unit) was recorded separately. Various plot sizes and shapes i.e., 1, 2, 4, 5, 8, 10, 16, 20, 25, 40, 50, 80, 100 and 200 basic units were formed (Table 1) by combining the adjacent units both length-wise and width-wise.

Statistical analysis: The coefficient of variation (average CV of 4 blocks) for all possible combinations of various plot sizes and shapes were calculated for seed yield as suggested by Gomez and Gomez (1984). The method of "Point of Maximum Curvature" was employed to obtain the optimum plot size which involved plotting a curve of the coefficient of variation in per cent (CV) against various plot sizes. The optimum plot size was considered the point on the curve where the rate of change in CV was found to be maximum. The number of replications ® for different plot sizes were worked out (Rambabu et al., 1980) by the formula:

$$r = \frac{(CV)^2}{P^2}$$

Where, P was the standard error of mean at 90% confidence interval. The total area required for an experiment was obtained by multiplying the plot size with the number of replications at P per cent SEm for different plot sizes. Land use efficiency for various plot sizes were computed with respect to 1 basic unit plot area.

Optimum plot size: The results revealed that the CV decreased with increase in plot size in either directions (Table 1). Similar results were reported by Lakhere et al. (1995). The average CV decreased from 54.78% to 5.63% with increase in plot size from 1 basic unit to 200 basic units. It is established fact that as the plot size increases, the cost of conducting the field experiment increasing rapidly. Therefore, per unit decrease in CV was also calculated. Per unit decrease in CV was observed from 14.05% to 0.79% with increase inn plot size from 2 units to 20 units plot size. Then after, the per unit reduction in CV was not proportionate to the units (i.e., area) added, hence, 20 unit plot size (i.e., 10.8 m^2) was considered as optimum plot size (net) for field experiments on irrigated castor. The same result can also be observed from Fig. 1. However, Reddy and Ramnatha Chetty (1983) reported a rectangular plot of size 18 m^2 with longer side across the crop rows as optimum plot size for dryland castor.

Optimum plot shape: For a fixed plot size, the plot shape indicated a consistent effect on CV. Long and narrow shape of plot showed less CV compared to compact plot. The CV was found less for plots having greater length than greater width. The CV calculated for 6 various shapes of 20 units optimum size of plot are presented in Table 1. The CV varies from 14.14% to 19.43% among 6 various shapes of 20 units plot size. Generally, one rows requires as border row around the net plot. Long and narrow shape of plot i.e., 20 x 1 and 1 x 20 are not preferable because of inconveniences in different agronomical field operations in the standing crop, though they gave minimum CV (i.e., 15.88% and 14.14%). Beside this, long and narrow shape of plot requires larger gross plot size i.e., 35.64 m^2. Comparatively high CV (18.55% and 19.43%) were observed for relatively square plots i.e., 5 x 4 and 4 x 5. Hence, considering the less CV

i.e., 16.75% and the feasibility of irrigation and other agronomic operations in the standing crop, 2 rows each of 10 dibbles (i.e., 2 x 10) was considered optimum shape of plot for irrigated castor.

Number of replications and relative land use efficiency: The number of replications and required area for different plot sizes at 10% standard error of mean were computed from the estimated CV for seed yield of castor (Table 2) showed that the number of replications and relative land use efficiency of the pot decreased as the size of plot increase. Similar results were obtained by Rambabu *et al.* (1980) and Sethi (1985). Due to practical inconvenience in irrigation and other agronomic operations in field experiments with small plot size, a plot size having relatively high efficiency with less number of replications should be considered for field experimentation (Ali and Singh, 1986). Such a situation observed for the 20 units plot size which is having considerably less number of replications (i.e., 3) and relatively high land use efficiency (50%) for seed yield. Therefore, 3 replications could be considered optimum for 20 units plot size at 10% probability level for seed yield.

Conclusion: Analysis of data observed from the uniformity trial indicated that a rectangular plot of 10.8 m^2 i.e., 2 rows each of 10 dibbles was found optimum net plot size for conducting field experiments on irrigated castor. The analysis further suggested that minimum 3 replications was optimum for 20 units plot size at 10% probability level for seed yield with relatively high (50%) land use efficiency.

Table 1 Coefficient of variation for various plot sizes and per unit decrease in CV for seed yield

Plot size (units)	Plot shape		Coefficient of variation (%)			
	No. of rows	No. of dibbles within row	Average of four blocks	Average for plot size	Decrease	Per unit decrease
1	1	1	54.78	54.78	-	14.05
2	2	1	41.12	40.73	14.05	4.85
	1	2	40.33			
4	4	1	31.43	31.03	9.70	2.71
	2	2	30.81			
	1	4	30.84			
5	5	1	29.17	28.32	2.71	1.16
	1	5	27.46			
8	4	2	24.72	24.85	3.47	1.40
	2	4	24.97			
10	10	1	22.39	22.04	2.81	0.28
	5	2	23.26			
	2	5	22.08			
	1	10	20.44			
16	4	4	20.34	20.34	1.70	0.79
20	20	1	15.88	17.17	3.17	-0.06
	10	2	18.25			
	5	4	18.55			
	4	5	19.43			
	2	10	16.75			
	1	20	14.14			
25	5	5	17.45	17.45	-0.28	0.26
40	20	2	13.65	13.62	3.83	0.02
	10	4	15.57			
	4	10	13.34			
	2	20	11.91			
50	10	5	13.26	13.47	0.15	0.11
	5	10	13.68			
80	20	4	10.72	10.10	3.37	0.01
	4	20	9.47			
100	20	5	10.08	9.90	0.20	0.04
	10	10	9.64			
	5	20	9.97			
200	20	10	6.38	5.63	4.27	
	10	20	4.87			

Table 2 Number of replications and area required for 10% SEm and relative land use efficiency for seed yield with respect to unit plot size

Plot size (units)	Coefficient of variation (CV)	No. of replications	Area required		Relative land use efficiency (%)
			Basic units	Sq. m.	
1	54.7	30	30	16.2	100.0
2	40.7	17	34	18.4	88.2
4	31.0	10	40	21.6	75.0
5	28.3	8	40	21.6	75.0
10	24.9	6	60	32.4	50.0
16	22.0	5	80	43.2	37.5
20	17.2	3	60	32.4	50.0
25	17.5	3	75	40.5	40.0
40	13.6	2	80	43.2	37.5
50	13.5	2	100	54.0	30.0
80	10.1	1	80	43.2	37.5
100	9.9	1	100	54.0	30.0
200	5.6	1	200	108.0	15.0

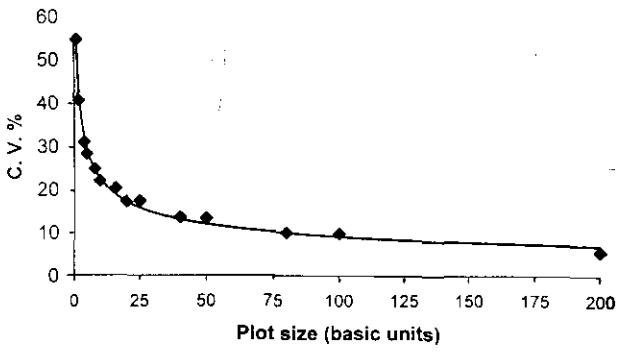

Fig. 1 Relationship between CV per cent and plot size

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J. Oilseeds Res., **23**(2) : **377-378 (2006)**

Short communication

Identification of castor, *Ricinus communis* L. genotypes for rainfed conditions[1]

M. Jyothi, Ramesh Thatikunta and Baby Akula

College of Agriculture, Acharya N.G. Ranga Agril. University, Rajendranagar, Hyderabad-500 030, AP

(Received: September, 2005; Revised: December, 2005; Accepted: February, 2006)

India ranks first in the castor, *Ricinus communis* L. production in the world with average productivity of 732 kg/ha from an area of 10.94 lakh ha. Its cultivation is mainly confined to the states of Andhra Pradesh, Karnataka, Tamil Nadu and Orissa. Andhra Pradesh is the major castor growing state with where it is chiefly grown during *kharif* under rainfed conditions. The intensity and duration of dry spells during the season are highly unpredictable leading to significant moisture stress at critical stages of crop growth like flowering and maturity of various order of spikes (Hanumantha Rao and Lavanya, 2003). Response of castor genotypes to aberrant weather conditions particularly water stress in kharif and their recovery/regrowth have not been adequately studied. Hence, the present investigation was taken up to study the physiological traits of different genotypes that contribute to drought tolerance and consequently high yields under rainfed conditions.

Six castor genotypes *viz.*, PCS 124, VP 1, Kranthi, PCS 136, PCS 137 and PCS 138 were sown in alfisols in randomized block design at the Agricultural College Farm, Rajendranagar during *kharif*, 2003. A spacing of 90 cm between rows and 30 cm between plants was maintained. Gross plot size was 4.5 x 4.5 m whereas the net plot size was 3.9 x 2.7 m with six replications. Need based interculture and plant protection measures were adopted. During the crop season 728.7 mm rainfall was received in 38 rainy days. The genotypes were evaluated for their response to water stress and their ability to recover and regrow upon relief from water stress. To assess the intensity of stress, soil moisture content was estimated gravimetrically from 15-30 cm depth. Stress occurred at two stages of crop growth *viz.*, at initiation of primary spike (30-44 DAS) and maturity of secondary and initiation of tertiary order spikes (75-104 DAS). Soil moisture content recorded was 6.2 % and 6 % during first and second dry spell and after the relief of water stress 8.7 %. The crop response to water stress and its recovery was quantified by recoding parameters like transpiration rate and leaf water potential (ψ_1) from second leaf from the top using steady state porometer and pressure bomb apparatus respectively. From the selected five plants, total dry matter (TDM), crop growth rate (CGR), specific leaf area (SLA), effective spike length, capsule number and seed yield were quantified. The results obtained were analyzed using two factorial RBD following the procedure of Panse and Sukhatme (1985).

The transpiration values of six castor genotypes varied significantly at both the stages *viz.*, during dry spell and after the relief of water stress (Table 1). Genotype PCS 136 under stress maintained high transpiration rate (32 $\mu g/m^2/s$) possibly to meet the atmospheric demand. However, reduced transpiration rates decreased the crop growth rates (CGR). Hence, identification of genotypes with low interdependency on water use efficiency (WUE) and transpiration are sought (Udayakumar *et al.*, 1998). After relief of water stress, transpiration rates increased (47 to 53 $\mu g/m^2/s$) and genotypes PCS 136 and VP 1 showed quick recovery.

Moisture stress decreased ψ_1 (- 1.05 to - 1.55 Mpa). Under stress Kranthi and PCS 137 maintained high ψ_1. Genotypes with high ψ_1 under stress are known to perform better (Uprety and Sirohi, 1985). After the relief of dry spell the l of the genotypes improved (- 0.6 to - 0.85 Mpa). Kranthi and PCS 137 recorded high ψ_1 indicating efficient water use pattern.

The genotypes recorded maximum total dry matter (TDM) at 90 DAS which declined by 29% at120 DAS (after relief of stress). During the dry spell the drymatter of the genotypes ranged from 37.1 to 46.9 $g/m^2/day$(Table 1). Under stress a reduction was observed in total drymatter (Babitha, 2003) and spike dry matter (Lakshmamma *et al.*, 2001) depending on the availability of soil water to plants. Reduction in leaf and stem dry matter reserves after 75 DAS and a consequent increase in spikes indicated preferential partitioning (Hanumantha Rao *et al.*, 1986). Two genotypes PCS 137 and 136 recorded higher TDM during and after the relief of dry spell.

[1] Part of M.Sc. (Ag.) Thesis of first author.

Crop growth rate (CGR) values decreased due to decreased TDM (Table 1). Kranthi and PCS 124 during dry spell and Kranthi followed by PCS 137 after dry spell proved superior in recovery and regrowth.

Specific leaf area (SLA) increased over the entire crop growth period. SLA at 120 DAS, during the recovery period was high (235.2 cm^2/g) as compared to the stress period at 90 DAS (204.9 cm^{-2}/g). A 5 to 11% decrease in SLA was recorded under moisture stress (Babitha, 2003). To tolerate stress, low SLA types with small thick leaves, well developed palisade with smaller cells are considered desirable. PCS 138 followed by PCS 124 maintained low SLA. PCS 137, PCS 136 and Kranthi owing to high CGR, recorded high SLA.

Kranthi recorded the maximum seed yield of 534 kg/ha followed by PCS 137 with 507 kg/ha. Seed yield is governed by number of capsules/plant (Ramesh and Venkateswarlu, 2001). Genotypes Kranthi and PCS 137 recorded the highest number of capsules on different order spikes compared to other genotypes (Table 1).

Yield reduced under moisture stress (Raghuram Reddy *et al.*, 1999). Yield reduction to the extent of 20% was observed in case of secondary spikes when moisture stress occurred during flowering of secondaries (Babitha, 2003).

Among the genotypes evaluated under rainfed conditions, Kranthi possessed superior characters like high ψ_1 high CGR, and high capsule number. PCS 137 showed characters like high ψ_1 and high TDM, high capsule number during and after dry spell. Thus, Kranthi and PCS 137 with superior physiological performance produced higher yields compared to other genotypes.

Table 1 Evaluation of castor genotypes for rainfed situation based on water status, growth and yield

Genotype	*Transpiration rate* ($\mu g/m^2/s$)		*Leaf water* potential (Mpa)		*Total drymatter* (g/m^2)		*Crop growth rate* (g/m^2)		*Specific leaf area* (cm^2/g		Capsule number			Seed yield/kg
	During dry spell	After dry spell	During dry spell	After dry spell	During dry spell	After dry spell	During dry spell	After dry spell	During dry spell	After dry spell	Primaries	Secon-daries	Tertiaries	
PCS 124	28	47	-1.35	-0.60	37.1	22.6	3.69	2.28	179.6	224.1	24	27	30	443
VP-1	30	50	-1.15	-0.70	42.2	31.1	3.21	-2.03	187.6	246.6	33	35	38	488
Kranthi	23	47	-1.55	-0.85	41.8	28.8	4.09	-2.47	261.6	232.1	40	41	46	534
PCS 136	32	53	-1.05	-0.60	44.5	32.2	3.24	-2.27	193.4	238.9	35	37	39	496
PCS 137	26	48	-1.47	-0.85	46.9	35.9	2.73	-2.31	235.4	242.1	38	40	44	507
PCS 138	28	49	-1.42	-0.60	39.8	28.2	2.71	-1.95	172.2	227.1	26	28	32	445
Mean	28	49	-1.33	-0.70	42.05	29.76	3.28	-2.21	204.9	235.2	32.58	34.56	38	486
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	SEm± CD (P=0.05)
Genotype (G)	0.32	0.63	0.02	0.14	0.22	0.43	0.08	0.15	15.65	30.67		1.21	2.36	2.73 4.42
DAS (D)	0.39	0.77	0.02	0.15	0.27	0.53	0.09	0.18	19.17	37.57		0.82	1.70	2.79 4.13
G x D	0.97	1.90	0.06	0.23	0.67	1.31	0.22	0.44	46.96	92.04		1.98	3.90	4.82 9.69

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J. Oilseeds Res., **23**(2) : **379-380 (2006)**

Short communication

High oleic and low linolenic acid in *Brassica rapa* var. toria

J.N. Sachan, Basudeo Singh, A.K. Singh, S.P. Singh, D.P. Pant, Rakesh Kumar and Sharad Pandey

Dept of Genetics and Plant Breeding, G.B. Pant University of Agriculture & Technology, Pantnagar-263 145, Uttaranchal

(Received: December, 2005; Revised: March, 2006; Accepted: June, 2006)

Rapeseed varieties grown in India contain a maximum of 20% oleic acid in oil. Increase of oleic acid content in oil results from reduced level of erucic acid, which is known to develop diseases like myocardial fibrosis in adults and lipidosis in children. High concentration of oleic acid lowers undesirable low density lipoproteins (LDL) without affecting the desirable high density lipoproteins (HDL) besides, improving its shelf-life. It also retains desirable levels of essential polyunsaturated fatty acids *viz.*, linoleic and linolenic. Rapeseed oil with 60% oleic acid, 20% linoleic and 10% linolenic acid is good for human nutrition. High oleic coupled with low linolenic contents reduce the formation of trans fatty acids, which increases the incidence of coronary diseases. Linolenic acid is important for oil quality and is the primary cause for flavour instability (Scarth *et al.*, 1991).

Tobin and Parkland cultivars of *Brassica rapa* var toria were used as source for the improvement in oleic (to increase) and linolenic (to decrease) acid contents. These were grown at Crop Research Centre, G.B. Pant University of Agriculture & Technology, Pantnagar (Uttaranchal), India during *rabi*, 2000-01 and bud pollination (selfing) in selected plants was attempted. Selfed seeds (S_0) obtained from 54 and 36 plants of Tobin and Parkland, respectively were analysed for fatty acid composition using Gas Chromatograph (GC). Extraction and methanolysis of oil from whole seeds and half-seed was carried out by modification of Hougen and Bodo (1973). The fatty acid composition was expressed as per cent of total fatty acids. Instrument used for fatty acid analysis was HP 5890 series II with capillary column at 250°C, detector at 280°C and injector at 260°C. Five high oleic and 5 low linolenic plants were selected from each of Tobin and Parkland and heir progenies were grown during 2001-02. Bud pollination was attempted and selfed seeds from 96 and 82 plants of Tobin and Parkland, respectively, were collected and analysed for fatty acid composition using bulk samples (8 to 10 seeds) from each plant. The plants with high oleic and low linolenic acid content were selected and half-seed (Downy and Harvey, 1993) was practiced in these selected plants during 2002-03. Only those half seedlings whose counter part one cotyledon (without axis) exhibited high oleic (>60%) and/or low linolenic (<5.5%) in analysis were grown in pots. Selected half-seed derived plants were maintained through bud pollination and harvested selfed seeds (S3) were analysed for fatty acid composition.

Fatty acid composition is an embryonic character, thus selfed (S_0) seeds of Tobin and Parkland obtained after first selfing were analysed for fatty acid composition and the desired types were selected (Table 1). The results presented in Table 1 revealed that in S_0 plants, oleic acid (18:1) ranged from 13.17 - 42.01% with a mean value of 26.74% in Tobin and 8.12-38.61% with a mean of 23.33% in Parkland. One of the essential fatty acids, linolenic acid (18:3) content ranged from 9.36 to 21.2% with a mean value of 15.01% in Tobin, while in Parkland, it ranged from 9.08-25.55% with a mean value of 16.51%. Oleic acid in five selected plants from Tobin ranged from 35.93 to 41.01% with a mean value of 37.6 and from Parkland ranged from 32.10 to 38.61% with a mean value of 36.22%. Linolenic acid which is a primary cause of flavour instability ranged from 9.36 to 11.14% with a mean value of 10.57% in plants selected from Tobin and from 9.00 to 11.17% with a mean value of 10.08% in Parkland. These results revealed an increase of 10.86 and 12.89% oleic acid in selected plants of Tobin and Parkland, respectively. Similarly, a reduction of 4.44 and 6.55% in selected plants from Tobin and Parkland, respectively was recorded for linolenic acid. Single plant selection has been used in the modification of linoleic (18:2) and linolenic (18:3) levels by Laakso *et al.* (1995) in turnip rape (*B. rapa*).

Bud pollinated plants of the progenies of selected plants (S_1) exhibited a further increase of oleic acid content in S_2 seeds of Tobin and Parkland and further decrease in linolenic acid contents in Tobin and Parkland which indicated the suitability of approach followed for modification of fatty acid composition.

Half seed selection followed by bud pollination in selected S_2 plants from Tobin and Parkland resulted in the identification of plants (S_3 seeds) containing oleic acid as high as, upto 70% in Tobin and Parkland. The plants with as low as, 3% linolenic acid content were also identified in Tobin. Oleic and linolenic acid contents in half seed

derived plants selections (Selfed S_3 seeds) was almost similar to the corresponding half-seed (one cotyledon) analysed for fatty acid contents. These results indicated the stability of these fatty acids in selected plants.

Identification of single plant with increased levels of oleic acid (69%) in spring turnip rape (*B. rapa*) was the basis for high oleic breeding programme described by Vilkki and Tanhuanpaa (1955). They used half seed technique to screen the single plant progeny followed by selfing and recurrent selection for high oleic acid content.

Acknowledgement: The financial assistance received from ICAR through NATP project and Director Experiment Station, GBPUA&T, Pantnagar for providing facilities for above investigation is thankfully acknowledged.

Table 1 Range and mean of oleic and linolenic acid contents (% of total fatty acids) of selections in different year

Year	Types of plants/seeds	Oleic acid (%)		Linolenic acid (%)	
		Tobin	Parkland	Tobin	Parkland
	Seed source	40.90	36.10	11.90	10.20
2000-01	**Selfed (S_0) Plants**				
	Range	13.17-42.01	8.12-38.61	9.36-21.21	9.08-25.25
	Mean	26.74 (42)	23.33 (36)	15.01 (42)	16.51 (36)
	Selected (S_0) Plants				
	Range	35.93-41.01 (5)	32.10-38.61 (5)	9.36-11.14 (5)	9.08-11.17 (5)
	Mean	37.60 (5)	36.22 (5)	10.57 (5)	9.96
2001-02	**Selfed (S_1) Plants**				
	Range	14.68-63.92	11.39-62.34	7.39-15.15	8.23-15.8
	Mean	36.16	31.41 (61)	10.67 (84)	12.23 (61)
	Selected (S_1) plants				
	Range	46.90-64.00	47.15-62.34	7.39-8.83	8.23-15.8
	Mean	53.53 (21)	52.71 (15)	11.58 (21)	13.87 (15)
2002-03	**Selfed (S_2) Plants Selected for Half Seed**				
	Range	63.92-64.0 (2)	62.34 (1)	-	-
	Mean	63.96 (2)	62.34 (1)	-	-
	Half Seed (one colyledon)				
	Range	60.50-75.1 (21)	63.72-72.4 (15)	**5.5-7.4 (12)**	**None < 6%**
	Mean	65.41 (21)	67.30 (15)	**7.03 (12)**	-
	Half Seed Derived Selfed (S_3) seeds				
	Range	58.74-68.0 (21)	52.57-70.14 (15)	3.03-5.43	-
	Mean	64.47 (21)	60.70 (15)	4.21 (12)	-

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from Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, India,
Ph : (040) 24016141/24015345; Fax : (040) 24017969
Computer Typesetting : **Sasi Graphics**, Rajendranagar, Hyderabad Printed by **M/s Progressive Press Pvt. Ltd**, Hyderabad