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Review Article

Growth, survival, perpetuation and pathogenic variability of *Sclerotium rolfsii*, a polyphagus pathogen - A review

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Abstract

***Sclerotium rolfsii* is a polyphagus fungus attacks most of the important crops in the tropical and subtropical conditions. Its necrotrophic nature provides it to survive in different conditions. The fungus survives mostly in the form of sclerotia. These resting spores attack the plants of different crops at different growing stage and monocropping system and use of high dose of chemical fertilizers has worsened the situation and severe losses were reported in many crops. To manage the diseases caused by *S. rolfsii*, the survival and multiplication, pathogenic variability and the factors responsible for it are very much important. In the present review an effort has been made to compile and synthesize the information available on the congenial conditions, burial depth, temperature and moisture responsible for long period survival, germination of sclerotia, variability in pathogen and disease development. So these can be well utilized for controlling the diseases caused by this fungus.**

Key words: *Sclerotium rolfsii*, growth, perpetuation, pathogenic variability

Introduction

S. rolfsii is widely distributed in tropics and in warmer parts of temperate zone. In India, it is widespread in almost all the states and cause economic losses on many crops. It is difficult to assess the losses caused by *S. rolfsii*, but the numerous reports from tropical and sub-tropical areas of the world, coupled with the large number of hosts attacked indicate that economic losses are substantial each year (Aycock, 1966). Losses range from mild on many hosts to total destruction of the crop in some species. Among the crops, soybean, peanut, sugar beet, pepper, tomato and potato suffer maximum losses, whereas sorghum, wheat, rice, lentil, betel vine, alfalfa, cotton, sugarcane, tobacco, sun hemp, sunflower, chrysanthemum, gladiolus and other ornamental species suffer minor damage.

Parts affected and symptoms produced

S. rolfsii preferentially attacks on stem, but it can infect any part of the plant including root, leaf, flower and fruit. On erect plant, yellowing and wilting are usually preceded by light to dark brown lesions at collar region of the stem adjacent to the ground. Drying or shriveling of the foliage and ultimately death of the plants occur after wilting. Characteristic sclerotia, at first white and later brown to black, are produced on mats of mycelium on the plant or soil.

The Pathogen

Sclerotium rolfsii produces white (when young) to pale (when old) mycelium, which characteristically grows in strands. The hyphae are hyaline, thin walled and sparsely septate when young. Older hyphae contain primary and secondary septa with conspicuous dipolar plates. Secondary hyphae 4-7 μm and shorter, whereas tertiary hyphae were only 2.0-4.5x4.0-7.0 μm. Clamp connections are usually numerous but vary with the type of mycelium or strain. *S. rolfsii* produces sclerotia, which are white to dark brown, globose to elliptical and about 0.5-2.0 mm in diameter. However, their size may vary with the strain and substrate. Mature sclerotia are composed of an outer melanized rind, two to four cell thick layers (Chet *et al.*, 1967; Chet and Henis 1968; Chet and Henis 1972; Liu *et al.*, 1977) an underlying cortical layer and an inner most medullary region comprised loosely interwoven hyphae (Nair *et al.*, 1969; Chet, 1975; Tu and Kimbrough 1978; Punja *et al.*, 1985).

The basidiospores are produced on mycelial mat on the host surface and each basidium (7.0-9.0 x 4.0-5.0 μm) bears 2 to 4 hyaline, one celled ovate, apiculate, smooth basidiospores (6.0-7.7 x 3.5-5.0 μm) borne on the sterigmata (2.5-6.0 μm). According to Goto (1934), basidiospores are forcibly ejected from the sterigmata. Discharged basidiospores contain 2-4 nuclei. Three germ tubes may develop within 24 h and produce multinucleate hyphae, which aggregate into strands giving a web-like or fan like appearance.

Factors affecting growth and germination of the pathogen

Effect of moisture on the growth of the pathogen

Sclerotial survival is very poor in moist soil than in dry soil (Bandara, 1980; Beute and Rodrìquez Kabana, 1981). They also observed that mycelium rapidly dries in the presence of high moisture at 15 and 35°C. However, it was viable for at least 6 months at 15 and 35 °C in dry soil. Mustafee and Chattopadhyay (1971) and Munnecke *et al.* (1982) observed less growth with increasing soil moisture content, which was also confirmed by Ramarao and Raju (1980), that the disease incidence was more in soil with water content below saturation level. However, Punja (1985) could not interpret the results obtained from studies on the effect of soil moisture (per cent moisture-holding capacity) and mycelial growth and disease development.

Effect of burial depth on the survival and germination of the pathogen

S. rolfsii is considered strongly aerobic fungus and germination of its sclerotia considerably reduced below soil surface (Abeygunawardena and Wood, 1957; Fazardo and Mandoz, 1935; Punja, 1986). Fazardo and Mandoza (1935) found only 60% and 15% germination when sclerotia buried 10 and 12 cm deep respectively as compared to 100% when they were buried at 2.5 and 5 cm deep. Sclerotia did not germinate at 15 cm depth. Herrera *et al.* (1986) reported 5 % mycelial survival at 25 cm depth after 7 months while sclerotia lost viability after 60 days. Smith *et al.* (1989) found about 11-31 % of the sclerotia that buried deeper than 2.5 cm survived after 30 days, regardless of sclerotial treatment (dry, washing) or source of sclerotia (soil or culture). In contrast 65-84 % of those on soil surface remained viable. Ansari *et al.* (2004) observed that burial depths affect viability and germination of sclerotia. Per cent germination and viability declined gradually however, the best viability was found at a depth of 7 to 9 cm for six months. They also found that the sclerotia remain viable up to 30 months but the viability was inversely proportional to the period of storage.

Based on controlled gaseous studies, Punja and Jenkins (1984 a) concluded that the inhibition in the sclerotial germination is not due to oxygen depletion or CO_2 or ethylene buildup. While this finding is consistent with the contentions of earlier investigators (Griffin and Nair, 1968; Coley-Smith and Cooke, 1971) it does not corroborate with the reports on the inhibitory effects of ethylene (Smith 1973; 1976). Physical pressure exerted by the weight of the soil over deeply buried sclerotia could in part account for the inhibition of germination, since metal weights placed over sclerotia at soil surface gave similar results (Punja and Jenkins, 1984a). Such mechanical stress may alter plasma membrane integrity and increases cyclic adenosine monophosphate (cAMP) levels (Pall, 1977), increases the exudation of nutrients and subsequent colonization of sclerotia of *S. rolfsii* by soil microorganisms (Punja and Jenkins, 1984a).

Sclerotium loses its viability when subjected to cycles of alternate drying and wetting. Coley-Smith and Cooke (1971) and Smith (1972) reported that cycles of drying and wetting enhances decays of sclerotia by increasing nutrient leakage and subsequent colonization by microorganisms, especially bacteria inhibitory to their germination.

Sclerotia are the survival structures of *S. rolfsii* and mainly lie in the soil. The sclerotial survival in the absence of host is largely dependent on the physical environment and nutritional availability. Povah (1927) reported that sclerotia could remain viable after 8-10 months, whereas they survived for 4 years in the laboratory. On the contrary it was reported that sclerotia remain dormant under high water potentials but germinate under low water potentials (Bandara,1980). Cooper (1964) found that mycelia and sclerotia disintegrate in waterlogged condition and reduces the disease severity of peanuts in North Carolina.

Sclerotial germination

Punja and Grogan (1981) and Ansari *et al.* (2004) have described two forms of germination, hyphal and eruptive. Hyphal germination is characterized by the growth of individual strands from the sclerotium surface; these hyphae originate from the cells of the medulla (Chet *et al*, 1977), but their growth is not extensive unless an external source of nutrients is available. In contrast, plug (s) or aggregates of mycelium bursting through the sclerotial rind characterize eruptive germination. Sclerotia can germinate eruptively only once, since internal stored materials are utilized during the growth of the mycelium. Eruptive germination is induced by drying sclerotia (Punja and Grogan, 1981), exposing them to volatile compounds (primarily alcohols and aldehydes) (Beute and Rodriguez-Kabana, 1979a; 1979b; 1981) and to lesser extent by brief sodium hypochlorite treatment (Lin Lan and Gilbert ,1973; Punja and Grogan, 1981). Mature sclerotia germinate readily and appear to have a very brief, if any, dormancy period. Punja (1985) has emphasised that the two types of germination may be important for epidemiological studies and distinguishing viability. Some workers (Punja and Grogan, 1982; Punja and Jenkins, 1984a; 1984b) have also reported the effects of nutritional, environmental, and biotic factors on eruptive sclerotial germination.

Sclerotia germinate best between 24-36°C, and germination does not occur below 8 °C or above 45°C. Alternate drying and wetting at 15 days interval, inundating the inoculated soil beyond six weeks and exposing the sclerotia to hot water treatment at 50 °C for 15 minutes produced deleterious effects on sclerotial viability (Lal, 1994). The mycelium is killed near freezing or at high temperatures above 40°C, but sclerotia can withstand -10 °C for 48 hours or 50°C for 1 hour (Mukhopadhyay, 1971).

Effect of quantity and placement of sclerotia on disease development

Chowdhury (1945) observed that in betel vine burial of sclerotia at 8 cm or more was ineffective in causing infection, but the plants get infected if the sclerotia were placed at the soil surface or 2.5 cm below. Infection was delayed at 5 cm. Sugha *et al.* (1991) reported that inoculum consisting of sclerotia and mycelium kept at 5 cm depth caused 100% seed rot of pigeon pea. Increasing the inoculum depth from 10 to 12 cm in the soil decreased seed rot and inoculum buried at 10 to 12 cm depth did not cause collar rot of chickpea. Hiramath (1992) also found that 2% inoculum was sufficient to produce high disease level in sunflower.

Punja (1985) reported that an average inoculum of 2.5 sclerotia! 100 cm^3 of soil resulted in 100 % infection of carrot root slices under glass house conditions. Many workers have found that an inoculum level of 500 (0.8 g) sclerotia in 3 kg of soil was optimum for the production of collar rot in chickpea (Gurha and Singh, 1982; Sugha *et al.* 1991). Jahangir *et al.* (1995) working on apple rootstock observed from micro plot and field studies that 5 sclerotia/g of dry soil resulted in 19.5 and 35.0% disease respectively. They further reported that placing sclerotia 3.0 cm from apple rootstock, 0.5 cm deep grown in containers in the field resulted in lower incidence than placing sclerotia in contact with the rootstock.

Khan and Kolte (1989) reported maximum pre emergence mortality of mustard seedlings with 15 g infested sorghum seeds/kg soil although this was not significantly different from the mortality obtained with 10 or 25 g/kg. While, Toribio and Rodriguez-Kabana (1992) observed seedling mortality increased with the increase of sclerotial number in case of lentil.

Infection of host tissue

The extent of mycelial growth from sclerotia in soil is influenced by the form of germination (eruptive or hyphal) and by the presence of volatile compounds, decaying plant tissues and soluble nutrients (Punja and Grogan, 1981; Punja and Jenkins, 1984 b). The maximum distance from the host surface over which mycelium from an eruptively germinating sclerotium can grow and infect without an exogenous nutrient source is a function of the fungal isolate, soil moisture, texture and depth (Punja, 1986), soil microflora (Punja, 1986), nitrogenous amendments (Punja *et al.*, 1985) and volatile compounds (Punja and Grogan, 1981), these in turn may influence infection efficiency (Punja, 1986). Mycelium from eruptively germinating sclerotia can infect host tissue without requiring an exogenous food base of non living organic matter provided they are located within the competence volume (Punja and Grogan, 1981).

S. rolfsii penetrates non-wounded host seedlings directly by the formation of appresoria (Nasbaum *et al.*, 1961). Penetration may also be affected through natural openings such as lenticels and stomata. The fungus is both inter and intra cellular.

S. rolfsii produces both pectinolytic and cellulolytic enzymes in culture and host tissues, and also some metabolites, namely oxalic acid. Higgins (1927) found that this fungus usually produces ample quantities of oxalate on a variety of media and plays a key role in aiding its pathogenic capabilities. Bateman and Beer (1965) have claimed that both oxalic acid and pectic enzymes are involved in the destruction of host tissues by the fungus and that two fungal products acting together are more effective than either alone. The importance of these enzymes in pathogenesis is yet to be fully documented.

Inoculation techniques for inducing disease

Chakraborty and Bhowmik (1983) evaluated a number of methods *viz.* tooth-pick, hypodennic syringe, soil infestation, root injury and cotton swab methods for inducing collar rot disease of sunflower. They found the highest seedling mortality (94.2%) in soil infestation method followed by tooth-pick method (64.6%).

Pathogenic variability

Many workers (Nakata ,1925a, b; Celino, 1936; Milthorpe, 1941; Maduewesi, 1974; Mukhopadhyay and Matheswaran,1980) have reported strain differences in addition to type of mycelium, size, shape and colour of sclerotia. Although isolates from a given area are frequently uniform, extreme variations in morphological characteristics have been noted in worldwide collections. Single basidiospore isolates from a single hymenium frequently show considerable variation in colour, markings, growth rate, size and number of sclerotia and pathogenicity. Ansari and Agnihotri (2000) on the basis of oxalic acid production in the culture filtrate and on pathogenicity test on a set of soybean varieties grouped the soybean isolates of *S. rolfsii* collected from different locations into 12 groups. Todd and Rayner (1980) found hyphal antagonism when field isolates (vegetative incompatibility) or single basidiospore strain (heterokaryon incompatibility) is paired. While the genetic and physiological basis of this incompatibility is unknown it may be a mechanism that preserves the identity of genetically dissimilar mycelia and restricts the exchange of cytoplasm and genetic materials (Catan, 1972). Thus genetically isolated sub-groups within the species are formed (Puhalla and Hummel, 1983; Punja and Grogan, 1983).

Mukhopadhyay and Matheswaran (1980) found considerable variation both in rate of oxalic acid production and also in protopectinase and polygalacturonase activities in nine sugar beet isolates.

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Effect of poultry manure, *sewage sludge and* urban garbage compost on yield, quality and economics of groundnut, *Arachis hypogaea* L.

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Abstract

Field experiments were conducted during the summer seasons of 2001-2002 and 2002-2003 at University of Agricultural Sciences, Bangalore to study the effect of composted poultry manure, sewage sludge and urban garbage compost on yield, quality and economics of groundnut. Conjunctive use of inorganics and organics (25:75:40 kg N, P_2O_5 and K_2O + 10t FYM/ha) recorded higher yield (pod, haulm, oil and protein) and economics (net returns and benefit cost ratio) compared to application of organic manures alone. Among different organic manures composted poultry manure performed better in terms of yield and economics and was followed by sewage sludge.

Key words: Poultry manure, sewage sludge, urban garbage compost, groundnut, economics

Introduction

The higher productivity of the food crops and green revolution era was achieved with high yielding, fertilizer responsive crop cultivars and increased fertilizer usage. Because of over emphasis on chemical farming deterioration of land took place and improvement in productivity slowed down along with very serious soil and water pollution problems. The recent energy crisis, the hike in the prices of the inorganic fertilizers and declining soil health and productivity necessitates the use of organic manures in crop production. But non- availability of sufficient quantity of FYM and other organic manures in rural areas divert the attention of cultivators and researchers to find alternate nutrient sources like poultry manure, urban garbage compost and sewages sludge. Urbanization and industrialization had led to generation of large volumes of urban garbage and sewage sludge. These organic wastes are rich in macro and micro nutrients. Utilization of these organic wastes in crop production not only solves the problem of nutrient demand but also the disposal problem of those organic wastes. Keeping all these things in the view a research programme was planned to test the efficacy of poultry manure, urban garbage compost and sewage sludge in groundnut production.

Materials and methods

Field experiments were conducted during summer seasons of 2001-2002 and 2002-2003 at Regional Research Station, University of Agricultural Sciences (UAS), Bangalore to study the efficacy of poultry manure, urban garbage compost and sewage sludge for groundnut production. These organic wastes were compared with recommended practice and farmyard manure (FYM). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were twelve treatments *viz.*, T_1: Absolute control, T_2: Recommended practice (25:75:40 kg N, P_2O_5 and K_2O + 10t FYM/ha), T_3: FYM @ equivalent to recommended N, T_4: T_3 + P_2O_5 and K_2O, T_5: Composted poultry manure (CPM) @ equivalent to recommended N, T_6: CPM + P_2O_5 and K_2O, T_7: Urban garbage compost (UGC) @ equivalent to recommended N, T_8: UGC + P_2O_5 and K_2O, T_9: Enriched urban garbage compost (EUGC) @ equivalent to recommended N, T_{10}: EUGC + P_2O_5 and K_2O, T_{11}: Sewage sludge (SS) @ equivalent to recommended N, T_{12} : SS + P_2O_5 and K_2O. In the recommended practice (T_2) the sources of inorganic NPK were urea, single super phosphate (SSP) and muriate of potash (MOP) respectively. In the treatments T_4, T_6, T_8, T_{10} and T_{12} the quantities of P_2O_5 and K_2O supplied by the respective organic manures were calculated and balance amount of P_2O_5 and K_2O were added through SSP and MOP, respectively to meet the recommended dose of P_2O_5 and K_2O. N, P_2O_5 and K_2O concentrations of FYM, composted poultry manure, urban garbage compost, enriched urban garbage compost and sewage sludge were 0.91, 0.42, 0.74; 1.96, 2.43, 0.61; 0.86, 0.61, 0.59; 1.36, 1.50, 0.96 and 1.63, 1.20, 0.56, respectively. Enriched and non-enriched urban garbage composts were obtained from Karnataka Compost Development Corporation (KCDC). Sewage sludge was collected from drying beds of sewer treatment plant, Hebbal, Bangalore. The experimental soil was red sandy clay loam, low in available N (188 kg/ha), medium in available P_2O_5 (37.5 kg/ha) and available K_2O (196 kg/ha) with soil pH of 6.3. Groundnut variety TMV-2 was sown and all the agronomic practices were adopted as per need of the crop. Not much variation in the climate was observed between crop periods of two years. Observations on growth parameters were taken at every 30 days interval and yield parameters were taken after the harvest of the crop. Data was subjected to statistical analysis to draw the conclusions.

Results and discussion

Two years pooled data indicates that application of 25:75:40 kg N, P_2O_5 and K_2O + 10t FYM/ha (recommended practice) recorded significantly higher pod and haulm yield (2955 kg/ha and 3.77 t/ha, respectively) compared to all other treatments (Table1). The higher pod yield with conjunctive use of organic and inorganic nutrient sources may be attributed to higher nutrient availability. Inorganic N fertilizer with organic sources is known to reduce the C: N ratio and stimulate mineralization of organic N (Kai and Wada, 1979; Sahoo and Panda,1999; Malligawada et al., 2000 and Kamble *et al.*, 2002). Among different organic manures composted poultry manure recorded significantly higher pod yield (2651 kg/ha) and haulm yield (3.49 t/ha). These results are in conformity with Talashilkar *et al.* (1997) and Dosani *et al.* (1999). This was attributed to faster mineralization of nutrients from composted poultry manure since it had narrow C:N ratio compared to other organic manures (Toor *et al.*, 2001). Next to composted poultry manure, sewage sludge (2207 kg/ha and 3.06 t/ha) and enriched urban garbage compost (2153 kg/ha and 3.01 t/ha) gave significantly higher pod and haulm yields compared to urban garbage compost. Higher yields with sewage sludge may be attributed to improved physico-chemical and biological properties of the soil. Favourable effect of sewage sludge on water holding capacity, bulk density, organic carbon, available nutrients, soil pH, EC, CEC and microbial population of the rhizosphere is well documented (Subbaiah and Sreeramulu, 1979; Garav *et al.*, 1986). Sewage sludge is not only a source of organic matter and primary nutrients (NPK) but also an excellent source of micronutrients (Kelling *et al.*, 1977; Sabey, 1980).

Table 1 Effect of different organic manures on yield, quality and yield components of groundnut (average of 2 years)

Treatment	Pod yield (kg/ha)	Haulm yield (t/ha)	Harvest index (HI)	Oil yield (kg/ha)	Protein yield (kg/ha)	Pod yield (g/plant)	Mature pods/plant	100 kernel weight (g)	Shelling (%)
T_1	875	1.42	0.38	246	113	3.2	9	22.8	62
T_2	2955	3.77	0.43	971	489	10.8	29	28.4	68
T_3	1678	2.44	0.42	514	244	6.1	16	24.1	65
T_4	1752	2.48	0.41	538	254	6.4	17	24.5	65
T_5	2651	3.49	0.43	834	398	9.6	26	26.8	66
T_6	2649	3.52	0.43	844	397	9.7	26	26.9	66
T_7	1708	2.58	0.39	522	247	6.2	17	23.9	65
T_8	1716	2.55	0.40	530	260	6.2	17	24.1	65
T_9	2153	3.01	0.41	669	319	7.8	21	25.2	65
T_{10}	2182	3.21	0.41	694	343	8.1	21	25.4	65
T_{11}	2207	3.06	0.41	668	304	7.9	21	25.5	65
T_{12}	2219	3.10	0.41	695	332	8.1	21	25.6	65
SEm±	82	0.11	0.01	24.42	14.69	0.3	0.7	0.2	0.9
CD (P=0.05)	232	0.31	0.030	69.51	41.82	0.7	1.9	0.9	2.6

T_1 = Control
T_2 = 25:75:40 kg N, P_2O_5, K_2O + 10 t FYM/ha
T_3 = FYM
T_4 = FYM + P_2O_5 and K_2O
T_5 = Composted poultry manure (CPM)
T_6 = CPM + P_2O_5 and K_2O
T_7 = Urban garbage composted (UGC)
T_8 = UGC + P_2O_5 and K_2O
T_9 = Enriched urban garbage compost (EUGC)
T_{10} = EUGC + P_2O_5 and K_2O
T_{11} = Sewage sludge (SS)
T_{12} = SS + P_2O_5 and K_2O

Enriched urban garbage compost recorded on par yields with sewage sludge. Several researchers reported about the yield benefits in different crops with enriched urban garbage compost (Sharanappa, 2002). Among different organic manures urban garbage compost (1708 kg/ha and 2.58 t/ha) and FYM (1678 kg/ha and 2.44 t/ha) showed lower pod yield and haulm yield but recorded significantly higher over control (875 kg/ha and 1.42 t/ha). This may be due to low concentration of nutrients in urban garbage compost and farmyard manure (FYM) and release of major nutrients in general and N in particular from FYM and urban garbage compost was rather small to meet adequately the requirements of groundnut. Gaur *et al.* (1984) had observed that lesser than 30% N in FYM was generally available to the first crop. Addition of balanced P_2O_5 and K_2O to the organic manures in T_4, T_6, T_8, T_{10} and T_{12} did not influence the pod and haulm yield significantly. It can be concluded that native phosphorus and potassium already present in the soil may be sufficient to meet crop requirements.

Pooled data indicated that application of recommended dose of fertilizer (RDF) + 10 t FYM/ha to the groundnut recorded significantly higher harvest index (0.439) compared to urban garbage compost (0.399) and FYM (0.408) and found on par with composted poultry manure (0.432), sewage sludge (0.419) and enriched urban garbage compost (0.417). Yield components and quality parameters (oil and protein yield) also followed the similar trend like pod and haulm yield. Conjunctive use of inorganics and organics (25:75: 40 kg N, P_2O_5 and K_2O + 10 t FYM/ha) recorded higher oil and protein yield (971 and 489 kg/ha, respectively) and was followed by composted poultry manure (834 and 398 kg/ha, respectively).

Regarding economics of groundnut production, net returns were maximum with RDF + 10 t FYM/ha (Rs. 45475) which was followed by composted poultry manure (Rs. 40717) and sewage sludge (Rs. 32888) (Table 2). The higher net returns with RDF + 10 t FYM/ha was attributed to maximum gross returns (Rs. 60771) realized with relatively lower cost of cultivation (Rs. 15296). The highest B:C ratio of 3.97 was obtained with the same treatment (RDF+ 10t FYM/ha). This was followed by composted poultry manure (3.94) and sewage sludge (3.47). However, lowest net returns and B:C ratio was obtained with urban garbage compost (Rs. 12349 and 1.54, respectively). This was due to higher cost of urban garbage compost (Rs. 900/t).

Table 2 Economics of cultivation of groundnut as influenced by different organic manures

Treatment	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T_1 : Control	10867	18177	7310	1.67
T_2 : 25:75:40 kg N, P_2O_5, K_2O + 10 t FYM/ha	15296	60771	45475	3.97
T_3 : FYM	14055	34688	20633	2.47
T_4 : FYM + P_2O_5 + K_2O	15421	36178	20757	2.35
T_5 : CPM	13867	54584	40717	3.94
T_6 : CPM + P_2O_5 + K_2O	13939	54562	40623	3.91
T_7 : UGC	23017	35366	12349	1.54
T_8 : UGC + P_2O_5 + K_2O	23954	35507	11553	1.48
T_9 : EUGC	21067	44465	23398	2.11
T_{10} : EUGC + P_2O_5 + K_2O	21227	45064	23837	2.12
T_{11} : SS	12617	45505	32888	3.61
T_{12} : SS + P_2O_5 + K_2O	13227	45862	32635	3.47

FYM = Rs. 250/t
Composted poultry manure = Rs. 500/t
Urban garbage compost = Rs. 900/t
Enriched urban garbage compost = Rs. 1200/t
Sewage sludge = Rs. 250/t

Groundnut pods = Rs. 1980/q
Groundnut seeds = Rs. 30/kg
N = Rs. 7.35/kg
P_2O_5 = Rs. 19/kg
K_2O = Rs. 8/kg
Labour charge = Rs. 45/person/day
Groundnut haulm = Rs. 600/t

It can be concluded that composted poultry manure and sewage sludge are the suitable organic manures for groundnut. Since sewage sludge is cheaper in cost and rich in nutrients, it can be used as an alterative to farmyard manure, which is bulky and not available in sufficient quantity. Further long term experiments are needed on effect of sewage sludge application on heavy metal accumulation in soil and plants.

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Effect of pre-sowing invigouration on seed quality parameters in *rabi*/summer groundnut, *Arachis hypogaea* L.

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Abstract

Storing of *rabi*/summer produced groundnut under ambient conditions and looses viability at a faster rate leading to low germinability and field emergence. Therefore, to improve seed quality parameters of such pods (seeds), seed invigouration/pre-sowing hydration was taken up with various chemicals during 2002 and 2003. Results revealed that, mean germination per cent over the treatments was more than the minimum standards of certification (70%) upto 5 months of storage. But, by 8 months of storage, the germination came down below 70%. However, invigouration/hydration of such 8 old seeds with $CaCl_2$ (0.5%) or ascorbic acid (50 ppm) or thiram (0.1%) resulted in maintenance of more than 70% germination. These treatments also maintained more field emergence, seedling vigour and seedling dry weight. Hence, technique of invigouration of aged seeds with the said chemicals can be effectively used to improve the seed quality

Key words: Pre-sowing treatments, invigouration, seed quality, groundnut

Introduction

In the present experimental site (North Eastern dry zone of Karnataka), for early *rabi*/summer sowing, the seed obtained from *rabi* produce of the previous year will be used, as the current year's *kharif* crop will not be harvested by the time of sowing. Further, the *rabi* produce will be generally exposed to high temperature during harvesting and drying, hence, leads to loss of seed viability (Kapri *et al.*, 2003) due to free radical induced membrane lipid peroxidation (Ponquett *et al.*, 1991). Use of such seeds would result in poor plant population in the field. To maintain proper plant stand, high seed rate or gap filling should be followed but, which are costly or inconvenient. Hence, improvement of such seeds would be of immense use to achieve higher seed germination and field emergence. In this direction, seed vigouration is one of the easy techniques to enhance germination through repair of membrane damage (Fu *et al.*, 1998), reduction of production of free radicals and lipid peroxides (Saha *et al.*, 1990) and reducing lag phase of imbibition (Brocklehurst and Dearman, 1983). Seed invigouration with $CaCl_2$ found to maintain membrane integrity and helps in production of free radical scavengers (Kapri *et al.*, 2003). Invigouration with $CaCl_2$ have shown improve seed germination (Anonymous, 2003), pod quality (Narayanaswamy and Shambhulingappa, 1998) and pod yield (Arjunan and Srinivasan, 1989). In this dry agro-climatic region such studies are not conducted and therefore to evaluate various invigouration chemicals on seed quality parameters the present study was carried out.

Materials and methods

The study was conducted during *rabi*/summer season of 2001-02 and 2002-03 using two varieties *viz.*, TMV-2 and KRG-1 at Seed Science and Technology Research Laboratory, RARS, Raichur situated in North Eastern dry zone of Karnataka. In both the years, the pods harvested during *rabi*/summer season were stored in gunny bag under ambient conditions. At monthly intervals, pods were drawn, shelled and uniform seeds were subjected to invigouration (pre-soaking) with various chemicals (list of chemicals are given with the results) for six hours in the seed to solution ratio of 1:2 (v/v) and dried back to original weight under shade. Then, such seeds were sown in four replicates (four plastic trays with 12 kg of sand) having 50 seeds in each replication, adequate quantity of water provided and kept in room germinator having temperature of 25±1°C and relative humidity of 75% of 10 days. On 11th day (10 days after sowing), seed quality parameters *viz.*, seed germination (%) in the laboratory, vigour index (seedling height x germination percentage) and seedling dry weight (mg/5 plants) were monitored by following procedure prescribed by the ISTA (Anonymous, 1999). Further, field emergence was conducted in the open field conditions on red loamy soils and the field emergence was counted on 15 days after sowing. The data was analysed in factorial CRD using dry soft statistical programme. The results of 2, 5 and 8 months after storage (MAS) only are presented.

Results and discussion

Invigouration of seeds on seed germination was found inconsistent over the stages of storage and the years as the significance was not observed all the stages (Table 1). Similar trend was reported by Jeng and Sung (1994).

However, at 8 months after storage (MAS), in both the years, I_6 (ascorbic acid 50 ppm), I_7 (thiram 0.1%) and I_{10} ($CaCl_2$, 0.5%) have maintained germination percentage of more than 70 which is the minimum standard as per the seed certification (Table 1) and these treatments were on par to each other. But, the control (no invigouration treatment, I0) had only 65.9 and 57.4% seed germination, respectively during 2002 and 2003 at eight MAS. Invigouration with $CaCl_2$ at the rate of 0.4% (Rangaswamy *et al.*, 1993) or 0.5% (Narayanaswamy and Shambhulingappa, 1998) found to hasten germination per cent compared to the control. Among the genotypes, during both the years, at two months after storage (MAS), TMV-2 has more germination percentage than KRG-1, whereas, at 5 and 8 months after storage, KRG-1 maintained more germination than TMV-2 suggesting the inconsistency among the genotypes.

Field emergence did not differ significantly between the invigouration treatments at 5 MAS during both the years and at 2 MAS during 2003. However, at 8 MAS, in both the years it was differed significantly (Table 2). At 8 MAS, invigouration for seeds with ascorbic acid (50 ppm), thiram (0.1%) and $CaCl_2$ (0.5%) resulted in field emergence percentage of 71.1, 70.4 and 70.4, respectively during 2002 and were on par to each other but significantly more than the control and other treatments. The same treatments remained the best during 2003 also. Similar to the present results, Narayanaswamy and Shambhulingappa (1998) have shown field emergence of 89.5% with $CaCl_2$ (0.5%) invigouration compared to control (no invigouration) value of 75.0% field emergence. Among the genotypes, KRG-1 relatively maintained more field emergence than TMV-2 at 5 and 8 MAS during both the years. But, at 2 MAS, it was more in case of TMV-2 than KRG-1. Similarly, Sandhya and Singh (1994) also found varied response of variety to the hydration treatment.

Vigour index differed significantly between the treatments at all the stages of storage and in both the years (Table 3). The mean vigour index decreased with storage duration (Table 3) and is mainly due to decreased germination percentage (Table 1). In general, the vigour is more important especially in aged seeds, in this regard, at 8 MAS, I6 (1834), I_7 (1825) and I_{10} (1824) during 2002 and I_6 (1472), I_7 (1400), I_{10} (1520) and I_2 (1410) during 2003 showed significantly more vigour index than control and other treatments. Among these treatments, though order of ranking differed with year, these treatments were on par to each other excepting I_{10} during 2003. Amongst the genotypes, TMV-2 had significantly more vigour index than KRG-1 at all stages in both the years, excepting at 8 MAS during 2002. High vigour index in TMV-2 is mainly attributed to plant height (data not shown) because, the germination percentage was less in TMV-2 than KRG-1 at 5 MAS in both the years and 8 MAS in 2003 (Table 1). These results suggest that, ti would be better to consider seedling dry weight for computing the vigour index in place of seedling height.

Seedling dry weight a measure of early seedling vigour, differed significantly between the invigouration treatments at any given period of storage and varieties (Table 4). With the storage duration, the seedling dry weight decreased during both the years, it could be due loss of energy for respiration with storage. Further, loss in dry weight was more during 2003 compared to 2002 due to high RH and temperature prevailed during pod drying. In 2002, at any given stage of storage period, treatments, I_6 or I_7 performed the best over other treatments including control. These treatments were followed by I_{10} or I_2. However, this trend was reversed in 2003 that is I_2 or I_{10} had highest seedling dry weight followed by I_6 or I_7. These results indicate that though ranking of treatment differs with year, invigouration enhances the seedling dry weight in aged seeds. Hence, invigouration is a useful technology to enhance early seedling weight significantly. More seedling dry weight in treatments of hydration with $CaCl_2$ can be attributed to increased elasticity and plasticity of cell walls due to priming leading to more absorption of water, stronger root system and seedling dry weight (Arjunan and Srinivasan, 1989). Similarly, I6 (ascorbic acid) used in the study contain vitamins and amino acids, hence, might have influenced the growth obviously. Further, I_7 (thiram) treatment would have protected the seed from infestation. Among the varieties, KRG-1 had maintained more seedling dry weight compared to TMV-2 at all the stages of storage period and in both the years of experimentation suggesting the advantage of variety, KRG-1 over the TMV-2 for this region.

Among the ten treatments tried, over the two years, based on the ranking by considering all the quality parameters, the three top ranked treatments for invigouration are presented with data (Table 5). $CaCl_2$ (0.5%) treatment showed highest for three parameters (field emergence, vigour index and seedling dry weight) out of four parameters considered. This was followed by ascorbic acid (50 ppm) for vigour index and seedling dry weight with highest germination per cent or hydration with thiram (0.1%) for field emergence. Hence, it is felt that, $CaCl_2$ (0.5%) may be used effectively for aged seeds to enhance the seed quality parameters.

Table 1 **Effect of pre-sowing invigouration and seed germination (%) in *rabi*/summer groundnut**

Invigouration Treatment	Concentration	Storage period (in months)					
		2002			2003		
		2	5	8	2	5	8
I_0 : Control		91.8 (73.4)	84.6 (67.0)	65.9 (54.3)	84.9 (67.1)	71.4 (57.5)	57.4 (49.3)
I_1 : Water		92.8 (74.6)	84.8 (67.1)	64.5 (53.5)	85.0 (67.2)	71.6 (57.8)	60.1 (50.8)
I_2 : $CaCl_2$	0.5%	92.6 (74.3)	87.6 (69.5)	67.1 (55.0)	85.6 (67.7)	76.1 (60.7)	67.6 (55.3)
I_3 : $CaCl_2$	1.0%	93.3 (75.1)	89.1 (70.8)	72.1 (58.1)	86.1 (68.1)	76.3 (60.9)	70.1 (56.9)
I_4 : KNO_3	2.0%	89.8 (71.5)	84.5 (66.8)	64.3 (53.4)	84.3 (66.7)	73.3 (58.9)	61.1 (51.4)
I_5 : NAA	25 ppm	90.3 (72.0)	85.0 (67.2)	63.9 (53.1)	85.6 (67.7)	73.4 (59.0)	59.4 (50.4)
I_6 : Ethrel	25 ppm	91.5 (73.1)	83.1 (65.8)	65.4 (54.0)	84.1 (66.5)	70.6 (57.2)	60.5 (51.1)
I_7 : Ascorbic acid	50 ppm	93.8 (75.7)	90.6 (72.2)	72.2 (58.2)	85.9 (67.9)	76.1 (60.7)	7.3 (57.0)
I_8 : Thiram solution	0.1%	93.0 (74.7)	88.0 (69.8)	72.0 (58.1)	84.6 (66.9)	76.1 (60.7)	7.00 (56.8)
I_9 : NaCl	1.0%	89.3 (70.9)	83.3 (65.9)	67.0 (55.0)	84.9 (67.1)	73.3 (58.9)	62.3 (52.1)
I_{10} : KH_2PO_4	1.0%	93.3 (75.1)	84.3 (66.7)	64.6 (53.5)	86.0 (68.0)	73.1 (58.8)	63.3 (52.7)
Mean		91.9 (73.6)	85.9 (67.9)	67.2 (55.1)	85.2 (67.4)	73.7 (59.2)	63.8 (53.0)
CD (P=0.05)		2.2	NS	2.2	NS	2.3	3.0
Genotypes							
KRG-1		90.9 (72.4)	86.2 (68.3)	68.5 (55.9)	83.9 (66.3)	74.6 (59.7)	65.0 (53.7)
TMV-2		93.0 (74.8)	85.6 (67.7)	65.9 (54.3)	86.5 (68.4)	72.9 (58.6)	62.6 (52.3)
CD (P=0.05)		1.2	NS	0.9	1.5	1.0	1.2

Values in parentheses indicate the arc sine transformed data.

Table 2 ***Effect of pre-sowing*** **invigouration on field emergence (%) in *rabi*/summer groundnut**

Invigouration Treatment	Concentration	Storage period (in months)					
		2002			2003		
		2	5	8	2	5	8
I_0 Control		89.6 (71.3)	82.3 (65.5)	63.6 (52.9)	81.9 (64.8)	67.1 (55.0)	51.3 (45.8)
I_1 : Water		91.6 (73.3)	82.0 (64.9)	60.8 (51.3)	82.1 (65.0)	68.4 (55.8)	56.1 (48.5)
I_2 : $CaCl_2$	0.5%	91.5 (73.1)	85.3 (65.7)	64.4 (53.4)	83.4 (66.0)	73.3 (58.9)	64.3 (53.3)
I_3 : $CaCl_2$	1.0%	91.8 (73.5)	85.3 (67.5)	70.4 (57.1)	81.8 (64.8)	74.1 (59.4)	69.3 (56.4)
I_4 : KNO_3	2.0%	88.5 (70.2)	80.3 (63.7)	60.5 (51.1)	81.3 (64.4)	69.6 (56.5)	57.6 (49.4)
I_5 : NAA	25 ppm	88.5 (70.2)	81.6 (64.7)	61.5 (51.7)	80.6 (63.9)	70.6 (57.2)	56.1 (48.5)
I_6 : Ethrel	25 ppm	90.3 (72.0)	82.3 (65.1)	63.4 (52.8)	81.8 (64.8)	67.6 (55.3)	55.4 (48.1)
I_7 : Ascorbic acid	50 ppm	92.0 (73.6)	86.0 (68.0)	71.1 (57.5)	82.4 (65.2)	73.4 (59.0)	67.6 (55.3)
I_8 : Thiram solution	0.1%	91.2 (72.7)	86.6 (68.6)	70.4 (57.0)	81.9 (64.8)	73.8 (59.1)	69.1 (56.2)
I_9 : NaCl	1.0%	89.6 (69.5)	81.6 (64.7)	63.9 (53.0)	80.9 (64.1)	70.9 (57.4)	58.4 (49.9)
I_{10} : KH_2PO_4	1.0%	91.5 (73.1)	81.6 (64.7)	61.5 (51.7)	81.1 (64.2)	70.1 (56.9)	57.0 (49.0)
Mean		90.3 (72.0)	83.2 (65.7)	64.7 (53.6)	81.7 (64.7)	70.8 (57.3)	60.1 (50.8)
CD (P=0.05)		1.3	NS	2.9	NS	NS	4.3
Genotypes							
KRG-1		89.1 (70.8)	83.4 (65.7)	66.0 (54.3)	81.0 (64.2)	71.8 (57.9)	61.4 (51.6)
TMV-2		91.6 (73.2)	83.0 (65.6)	63.5 (52.8)	82.4 (65.2)	69.8 (56.7)	58.9 (50.1)
CD (P=0.05)		0.7	NS	1.3	NS	1.3	NS

Values in parentheses indicate the arc sine transformed data.

Table 3 Effect of pre-sowing invigouration on vigour index in *rabi*/summer groundnut

Invigouration Treatment	Concentration	Storage period (in months)					
		2002			2003		
		2	5	8	2	5	8
I_0 : Control		2534	2306	1614	2088	1675	1232
I_1 : Water		2697	2371	1588	2083	1642	1184
I_2 : $CaCl_2$	0.5%	2619	2319	1679	2148	1782	1410
I_3 : $CaCl_2$	1.0%	2648	2281	1824	2262	1886	1520
I_4 : KNO_3	2.0%	2492	2225	1610	1983	1662	1270
I_5 : NAA	25 ppm	2509	2206	1603	2084	1717	1322
I_6 : Ethrel	25 ppm	2534	2200	1638	2133	1707	1340
I_7 : Ascorbic acid	50 ppm	2705	2488	1834	2292	1855	1472
I_8 : Thiram solution	0.1%	2687	2466	1825	2226	1767	1400
I_9 : NaCl	1.0%	2476	2298	1630	2027	1728	1310
I_{10} : KH_2PO_4	1.0%	2621	2290	1574	2168	1762	1324
Mean		2593	2314	1674	2135	1744	1343
CD (P=0.05)		15.2	6506	9.9	47.6	47.8	72.2
Genotypes							
KRG-1		2488	2263	1681	20.27	1670	1255
TMV-2		2698	2364	1886	2244	1818	1432
CD (P=0.05)		13.5	28.0	4.2	20.3	20.4	30.8

Table 4 Effect of pre-sowing invigouration on seedling dry weight (mg/5 plants) in *rabi*/summer groundnut

Invigouration Treatment	Concentration	Storage period (in months)					
		2002			2003		
		2	5	8	2	5	8
I_0 : Control		1359	1288	1146	1107	893	712
I_1 : Water		1436	1313	1141	1120	889	703
I_2 : $CaCl_2$	0.5%	1510	1353	1173	1270	1050	905
I_3 : $CaCl_2$	1.0%	1524	1349	1191	1285	1053	921
I_4 : KNO_3	2.0%	1364	1307	1121	1137	863	710
I_5 : NAA	25 ppm	1432	1350	1129	1130	927	785
I_6 : Ethrel	25 ppm	1450	1358	1142	1121	922	793
I_7 : Ascorbic acid	50 ppm	1519	1418	1237	1227	995	863
I_8 : Thiram solution	0.1%	1533	1412	1219	1176	974	845
I_9 : NaCl	1.0%	1372	1325	1136	1149	927	800
I_{10} : KH_2PO_4	1.0%	1467	1296	1125	1155	928	798
Mean		1451	1343	1160	1170	947	803
CD (P=0.05)		26.4	14.5	6.5	46.3	45.2	39.2
Genotypes							
KRG-1		1500	1410	1179	1206	987	833
TMV-2		1402	1276	1142	1135	907	774
CD (P=0.05)		16.8	19.3	2.8	19.8	19.3	16.7

Table 5 **Per cent improvement of seed quality parameters due to invigouration treatments over the control of 8 months after storage (pooled data of 2002 and 2003) in *rabi/*summer groundnut**

Invigouration Treatment	Concentration	Germination (%)	Field emergence (%)	Vigour index	Seedling dry weight
I_2 : $CaCl_2$	0.5%	15.7	16.2	13.0	20.7
I_7 : Ascorbic acid	50 ppm	15.2	13.3	11.1	21.4
I_8 : Thiram solution	0.1%	15.3	17.5	13.7	21.6

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Genetics of yield and its component characters in Indian mustard, *Brassica juncea* (L.) Czern & Coss under rainfed conditions

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Abstract

Three single crosses involving four rowed Indian mustard, *Brassica juncea* as a female parent and cultivars, Laxmi, Varuna and RH-30 as male parents using six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) were analysed for estimation of gene effects under rainfed conditions. The F_1 of all the crosses registered better parent heterosis except for cross II for plant height. Invariably superior performance of F_2 and back crosses over F_1 and parents, respectively for seed yield in cross II suggested the role of non-additive interactions. The deviation in Mather's (1949) ABC scaling tests and that of Cavalli's (1952) joint scaling test advocated the inadequacy of three parameters (m, d, h) model for plant height and seed yield in all the three crosses, seeds/siliqua in cross II and III and siliqua length in cross III. It was confirmed that testing for four and five parameter models, in case of inadequacy of three parameters, before directly switching over to six parameters model was essential to get correct picture of inheritance of the characters. Invariably, both additive and dominance gene effects were important with preponderance of the latter. Duplicate epistasis formed an important component of digenic interactions in the inheritance of seeds/siliqua and seed yield in cross II.

Key words: *Brassica juncea,* gene effects, non-allelic interactions, seed yield

Introduction

Indian mustard, [*Brassica juncea* (L.) Czern and Coss] is the second important oilseeds grown mainly as a pure crop in rainfed areas of the country. Recently, a four rowed mustard variety RB-24 (Geeta) has been released for cultivation in north-western parts of India under rainfed conditions. It gives higher seed yield than normal two rowed check varieties under rainfed conditions. Genetic variability for seed yield and other traits is reported to be less in this crop (Uddin *et al.*, 1983). Although there is ample information on genetic control of seed yield and its component characters under irrigated conditions (Chauhan and Singh, 1979; Yadava *et al.*, 1981; Ramdhari and Yadava, 1983; Yadav *et al.*, 1993), the genetic information under rainfed condition is very scanty (Kumar and Yadav, 1986) and not available involving a four-rowed Indian mustard as a parent.

The developments in statistical genetics have made possible to study the various facets of the operation of quantitative genes and to use this information in formulating appropriate breeding strategy to effect genetic improvement of traits under moisture stress/rainfed conditions. The present study, therefore, was aimed at studying the genetics of important quantitative characters including seed yield under rainfed conditions so as to formulate suitable breeding strategy.

Material and methods

The experimental material for the present study comprised a set of six generations *viz.*, P_1, P_2, F_1, F_2, BC_1, BC_2 of each of three crosses RB-24 x Laxmi, RB-24 x Varuna and RB-24 x RH-30. Of these parents, RB-9901 (RB-24) is a recently released four-rowed mustard variety (Anonymous, 2002). Other three varieties are two rowed widely grown in northern India. The six generations of three crosses were planted in a Randomized Block Design with three replications at CCS Haryana Agricultural University, Regional Research Station, Bawal under rainfed conditions during 2001-02. Each non-segregating generation (P_1, P_2, F_1) was grown in two rows. Among segregating generations backcrosses were planted in three rows and F_2s were sown in six rows. Rows were 5 m long with spacing of 45 cm between rows and 15 cm between plants. Data on plant height (cm), siliqua length (cm), seeds/siliqua and seed yield/plant (g) were recorded on 5 randomly selected plants in each row in each replication. First (Mather's 1949) scaling tests and then the joint scaling test of (Cavalli, 1952) were applied to test the adequacy of additive-dominance (m, d, h) model. In case of inadequacy of additive-dominance model four [(m, d, h, i); (m, d, h, j); (m, d, h, l)] and five [(m, d, h, i, j); (m, d, h, i, l); (m, d, h, j, l)] of the six parameters were fitted successively following Cavalli (1952) for estimation of genetic parameters. These were compared against χ^2 value for their respective degree of freedom. The

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adequacy of the four and five parameter models was tested by the non-significant variation tested from χ^2 values. Where, all the generations were used for parameter estimation, the fitness of the six-parameter model could not be tested by χ^2 test and regression analysis. The significance of the parameters was tested against their corresponding standard errors.

Results and discussion

The F_1 mean of all the crosses exceeded mid-parent and better parent values for seed yield and plant height except in case of cross II for plant height (Table 1) indicating high heterosis and role of over-dominance in expression of these characters. The F_2 mean also exceeded the respective F_1 and parents in case of cross II for seed yield indicating the scope for transgression. Both back crosses excelled the respective parents for siliqua length in cross III and for seed yield in cross I and II indicating the role of non-allelic interactions in the inheritance of these characters. Similar observations in mustard under irrigated condition were reported by Pal and Singh (1986) and Kumar *et al.* (2002).

Mather's (1949), A B C scaling tests showed inadequacy of additive-dominance model i.e., indicated the presence of non-allelic interactions (Table 2) for plant height and seed yield in all the three crosses, for seeds/siliqua in cross II and III and siliqua length in cross III showing existence of inter-allelic interactions in genetic control of these characters. The joint scaling test also vouched for inadequacy of the three parameters (m, d, h) model for all the above mentioned characters with significant Chi-square value.

Sagar (1990) suggested that before switching over to six parameter model, it was important to test for four [(m, d, h, i); (m, d, h, j); (m, d, h, l)] and five [(m, d, h, i, j); (m, d, h, i, l); (m, d, h, j, l)] parameter models to find the best fit model. In the present case four and five parameters model were found adequate for all the characters in all the three crosses (Table 2). While dominant effects were invariably significant and preponderant for all the characters in all the three crosses except seeds/siliqua and seed yield in cross III where additive effect were significant and preponderant. Preponderance of dominant effects at increased level for seed yield and its contributing traits lends support from the earlier reports by Pal and Singh (1986) and Kumar *et al.* (2002). The relative contribution of the additive and non-additive gene effects differed in crosses suggesting that inheritance of these characters is complex. Similar results were also reported by Thukral and Singh (1986).

Table 1 Mean performance of six generations of three Indian mustard crosses for various quantitative characters under rainfed conditions

Cross No.	Cross Name	P_1	P_2	F_1	F_2	BC_1	BC_2
				Plant height (cm)			
I	RB-24 x Laxmi	205.6*	199.9	214.1	186.3	200.0	203.5
II	RB-24 x Varuna	202.4	210.7	203.6	196.4	199.4	182.2
III	RB-24 x RH-30	207.6	213.2	221.1	203.2	207.4	204.9
				Siliqua length (cm)			
I	RB-24 x Laxmi	3.12	4.23	4.03	3.78	3.58	4.07
II	RB-24 x Varuna	3.52	3.93	3.63	3.69	3.50	3.94
III	RB-24 x RH-30	3.15	3.77	3.77	3.49	3.34	4.16
				Seeds/siliqua			
I	RB-24 x Laxmi	18.91	16.60	14.60	15.98	15.76	15.33
II	RB-24 x Varuna	18.66	15.40	15.40	14.40	13.78	14.02
III	RB-24 x RH-30	19.20	14.28	14.24	14.20	15.86	14.82
				Seed yield/plant (g)			
I	RB-24 x Laxmi	60.00	52.77	76.66	46.10	69.33	65.33
II	RB-24 x Varuna	42.44	36.11	55.55	58.00	69.00	97.00
III	RB-24 x RH-30	48.88	45.55	46.11	46.26	40.66	55.33

* Each value is a mean of three replications.

Table 2 Scaling test and estimation of gene effects for different characters in Indian mustard under rainfed conditions

Test	Cross I				Cross II				Cross III			
	Plant height (cm)	Siliqua length (cm)	Seeds/ siliqua	Seed yield/plant (g)	Plant height (cm)	Siliqua length (cm)	Seeds/ siliqua	Seed yield/plant (g)	Plant height (cm)	Siliqua length (cm)	Seeds/ siliqua	Seed yield/plant (g)
Scaling test												
A	-19.67*	0.004	-1.990	2.00*	-7.20*	-0.160	-6.58*	40.20*	-13.87*	-0.250	-1.68	-13.66*
B	6.93*	-0.200	-0.530	1.22	-49.8*	0.310	-2.85*	103.0*	24.60*	0.760	1.12	18.99*
C	-88.60*	-0.300	-0.790	-81.71*	-34.5*	0.030	-7.46	42.30*	-50.33*	-0.500	-5.15*	-1.60
3 parameter model												
m	197.9	3.640	17.64	54.85	204.5	3.73	16.81	40.20	207.1	3.47	16.39	47.86
d	0.892	-0.540	1.09*	3.22	-3.01	-0.240*	1.58*	3.22*	-3.10	-0.480*	2.17*	-2.55
h	11.10*	0.370*	-3.35*	17.32*	-8.30	-0.085	1.84*	29.26*	4.06	0.240	-2.54*	-1.25
χ^2	27.37*	0.770	1.39	11.98*	7.70*	1.031	16.96*	24.32*	11.12*	16.63*	11.79*	0.596*
4, 5, 6 parameter model												
m	164.5			24.34	188.4		17.10	-27.59	184.7	3.15	14.44	47.56
d	1.40			3.18	-2.63		1.35*	2.70	-2.35	-0.330*	2.26*	1.66
h	50.50*			54.32*	14.00		-9.74*	259.2*	35.41*	0.740*	-0.060	-1.14
i	38.77*			32.66*	18.00		-	66.83	25.46*	0.370	2.33*	-
j	-			-	-		-	-	-	-0.990*	-	-33.08*
l	-			-	-		8.12*	176.1*	-	-	-	-
χ^2	3.42			3.95	4.56		2.27	5.70	0.958	4.59	4.41	0.172
Type of epistasis	-			-	-		D	D	-	-	-	-

* Represents significant values

Among digenic interactions additive x additive effects were significant and positive for plant height in cross I and III, seeds/siliqua in cross III and seed yield in cross I.

These characters are expected to be fixed in a breeding programme relying on pedigree selection. Seeds/siliqua and seed yield in cross II showed significant dominant x dominant type of interaction and role of duplicate epistasis as the signs of (l) and (h) in the inheritance of these characters were opposite. Similar results were also reported by Pal and Kumar (1993); Singh and Srivastava (1999) and Kumar *et al.* (2002). The duplicate epistasis generally hinders the improvement through selection and higher magnitude of dominance x dominance gene effects would not be fixed. Selection for improvement of these characters in cross II under rainfed conditions has to be delayed to several generations until a high level of gene fixation is attained. Therefore, growing large populations in segregating generation and intermating followed by delayed selection to get transgressive segregants would be the right approach under such situations. The adequacy of additive-dominance model in case of siliqua length in cross I and II and seeds/siliqua in cross II suggested that improvement for these traits using cross II can be effected by recurrent selection for *sca* which capitalizes the dominant variance.

The F_1 of all these three crosses were having normal two rowed siliqua but in F_2, plants of four rowed siliqua appeared. These four-rowed plants can be improved further by following pedigree selection till this character is fixed. Four rowed siliqua plants have higher number of seeds/siliqua, long main raceme having more siliquae, higher oil content and moderately resistant to white rust. This will prove useful in improving the mustard crop. It is concluded that seed yield can be improved by following pedigree selection as it was controlled by positive and significant additive x additive effect.

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Partitioning coefficients of plant parts under different growth stages and environments in Indian mustard, *Brassica juncea* (L.) Czern and Coss

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Abstract

The values of partitioning coefficients in Indian mustard, *Brassica juncea* (L.) Czern and Coss. were recorded higher for root at 50 DAS and stem at 100 DAS and at harvest under both the environments. Although, partitioning coefficients for stem and siliquae observed nearly equal at harvest under both the environments. Siliquae partitioning coefficient observed significantly higher at 100 DAS under terminal moisture stress indicated the better mobilization of photosynthates. The root partitioning coefficient increased upto 50 DAS, declined thereafter until harvest under both the environments. However, at 100 DAS terminal moisture stress reduced stem partitioning coefficient more than that of root partitioning coefficient. Genotype Rajat x RH 819 recorded for higher seed partitioning coefficient and harvest index at harvest under both the environments. Whereas, siliquae partitioning coefficient was recorded higher in genotype BIO 902 x RH 8812 and Rajat x BIO 902 under normal and terminal moisture stress environments,

Key words: Partitioning coefficient, growth stages, environments, Indian mustard

Introduction

Oilseed brassicae, Indian mustard [*Brassica juncea* (L.) Czern & Coss] is one of the important crops of the country. The productivity of Indian mustard has not increased substantially despite selection and intensive breeding programmes, because it is a crop of Indian sub-continent and therefore, limited in its geographic distribution.

The shoot and root together are in constant competition for water, nutrients and metabolic products and the optimum proportion between these parts should be reached if the final yield is to be maximized. However, production efficiency of plant is also affected by the genotype and also environment. Breeders give attention mostly to aerial plant parts, because of the time, cost and methodological difficulties in root examination, the root characteristics play most vital role in crop growth and adaptation in different environments. Therefore, keeping this in view, the attempts have been made to understand the partitioning of biomass in Indian mustard.

Materials and methods

The experimental material comprised of eight varieties *viz.*, Rajat, PCR-10, DHR-9401, RH-30, BIO 902, RH 819 and RH 8812 of Indian mustard selected on the basis of their phenotypic diversity for morphological, agronomical characteristics, tolerance against moisture stress and seed yield. These eight Indian mustard elite genotypes were crossed in diallel fashion, excluding reciprocals during 1998-99. During 1999-2000 *rabi* season, F_1 seeds of all the eight parental lines and their 28 crosses were evaluated in Randomized Block Design with three replications under normal and moisture stress environments in concrete drought plots (6x1x1.5 m) filled with dunal sand at the experimental farm of Drought Research Project, Directorate of Research, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana. The terminal moisture stress was imposed by the holding irrigation after 50 DAS. The partitioning coefficients of different parts of five randomly selected plants were worked out in mg at 50 DAS, 100 DAS and at harvest by using dry weights i.e., root, stem, leaf, siliqua, seed and total. The plants were separated in different plant parts and dried in oven by gradually increasing the temperature upto 60°C for a period of 72 hours. The data for different characters were statistically analyzed as per Kempthorne (1952).

Results and discussion

Perusal of data revealed that the value of partitioning coefficient was recorded higher for root followed by leaf and stem at 50 DAS, whereas, at 100 DAS stem followed by siliqua and root recorded for the highest partitioning coefficients under normal environments (Table 1 and 2).

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Table 1 **Per se performance of plant part partitioning coefficients at different growth stages under normal environment in Indian mustard**

Genotype	50 DAS			100 DAS					Harvest					H.I.
	Root	Stem	Leaf	Root	Stem	Leaf	Siliqua	Seed	Root	Stem	Leaf	Siliqua	Seed	
Rajat	417.0	150.3	432.7	169.7	492.0*	162.0	175.0	109.7	137.0	375.3	76.7	410.7	289.6*	24.2
Rajat x PCR-10	377.3	176.0*	447.0	148.3	389.3	148.7	314.3*	213.0*	107.0	414.7	81.0	397.7	227.7	22.8
Rajat x DHR-9401	322.0	268.0*	41.03	198.3	434.3	145.7	221.7	143.7	136.7	369.3	65.7	428.6*	282.3*	28.2*
Rajat x RH-30	421.0	133.7	445.0	165.7	401.0	161.3	272.0*	196.6*	160.7	363.7	99.6*	375.7	213.7	21.4
Rajat x Varuna	445.3	104.0	451.0	150.0	482.0*	147.0	221.0	144.7	114.0	398.3	68.0	420.0*	268.6*	26.9*
Rajat x BIO 902	479.7	39.0	481.3	163.0	472.7	149.3	205.3	123.7	120.3	368.0	80.3	431.6*	257.3	25.7*
Rajat x RH 819	379.7	80.0	540.3*	176.0	417.3	147.3	258.7	152.7	130.7	386.7	84.3	417.6*	300.3*	30.0*
Rajat x RH 8812	433.0	152.0	414.7	222.0*	435.3	158.0	185.0	133.7	153.3	357.7	75.7	413.7	249.7	25.0
PCR-10	561.7*	77.7	360.0	168.3	493.6*	205.6*	131.7	56.3	129.0	366.3	97.6*	407.0	214.3	20.5
PCR-10 x DHR-9401	409.3	141.3	449.0	168.7	349.7	234.6*	246.7	130.7	149.0	387.7	118.0*	345.0	224.0	22.4
PCR-10 x RH 30	402.0	85.0	513.0*	151.7	518.3*	114.0	216.0	141.0	128.7	405.7	60.0	405.7	232.3	23.3
PCR-10 x Varuna	465.3	90.0	444.0	175.3	505.3*	148.0	170.0	104.0	134.0	435.3*	58.7	372.0	196.0	19.6
PCR-10 x BIO 902	489.0	105.3	405.7	141.3	454.7	171.7	232.3	138.3	115.3	374.3	79.3	430.3*	247.7	24.7
PCR-10 x RH 819	437.0	96.3	466.7	166.0	463.7	175.7	194.7	105.0	148.3	381.0	101.3*	368.7	226.7	22.7
PCR-10 x RH 8812	563.0*	73.3	363.0	242.67*	304.7	176.0	276.6*	175.6*	185.0*	384.7	93.6*	336.3	179.3	18.0
DHR-9401	589.0*	77.3	333.3	149.7	469.0	166.0	215.3	101.3	137.7	370.7	75.0	416.0*	265.6*	26.6*
DHR-9401 x RH 30	407.0	202.0*	391.0	150.3	489.0*	173.0	187.3	109.7	137.3	425.3	86.7	350.3	195.7	19.6
DHR-9401 x Varuna	558.0*	52.3	390.0	171.7	311.0	227.6*	279.3*	151.7	169.6*	369.7	96.3*	364.0	177.7	17.8
DHR-9401 x BIO 902	451.3	119.3	429.0	197.0	395.0	142.3	266.0*	139.0	173.6*	406.7	67.3	351.7	191.0	19.1
DHR-9401 x RH 819	440.7	53.3	506.3*	151.3	516.6*	139.0	192.3	85.0	125.7	451.3*	63.0	360.0	203.0	20.3
DHR-9401 x RH 8812	496.0	89.3	415.0	207.7	372.3	152.0	268.3*	124.7	175.3*	322.7	75.0	427.0*	217.3	21.7
RH 30	437.0	266.3*	296.7	154.3	438.3	163.0	245.0	174.3*	144.0	375.7	97.3*	387.0	222.7	22.3
RH 30 x Varuna	487.7	110.0	401.7	151.7	432.3	140.0	276.0*	175.6*	148.0	403.3	63.3	385.0	278.6*	27.8*
RH 30 x BIO 902	589.6*	75.7	335.0	164.3	570.0*	147.0	119.0	70.3	119.3	447.3*	62.7	370.7	200.0	20.0
RH 30 x RH 819	518.0	96.7	385.7	188.3	441.0	92.3	266.3*	146.3	152.0	415.0	44.3	388.3	228.0	22.8
RH 30 x RH 8812	613.6*	82.0	304.3	196.3	452.7	135.0	216.3	141.7	159.0	380.0	68.0	393.0	206.3	20.6
Varuna	524.7	183.6*	251.3	187.7	441.0	144.0	227.3	132.3	155.3	421.3	84.3	339.0	159.3	16.0
Varuna x BIO 902	384.3	178.0*	437.7	155.0	478.7	104.7	310.6*	180.3*	116.7	431.0	46.7	405.3	197.3	19.7
Varuna x RH 819	502.3	152.7	344.7	175.3	451.3	160.7	213.0	133.0	156.7	350.7	65.7	427.0*	449.0*	24.8
Varuna x RH 8812	433.0	140.7	426.3	169.0	474.7	109.3	247.3	143.3	143.3	392.3	72.3	391.7	215.7	21.6
BIO 902	342.3	228.3*	422.7	210.3	387.0	134.7	268.3*	152.3	155.0	433.3*	82.0	329.0	191.0	19.1
BIO 902 x RH 819	473.3	170.6*	356.3	203.7	390.7	109.0	297.0*	180.3*	174.0*	385.0	64.7	376.3	194.3	19.4
BIO 902 x RH 8812	279.7	199.3*	503.3*	141.7	435.7	126.3	296.3*	173.6*	119.0	364.3	65.3	451.3*	239.7	24.0
RH 819	356.3	178.6*	465.3	299.3*	370.7	173.3	156.7	99.3	219.6*	420.3	77.0	283.0	132.7	13.3
RH 819 x RH 8812	599.3*	76.7	321.0	151.7	502.3*	155.3	150.7	90.0	116.3	469.0*	57.0	357.7	177.3	17.7
RH 8812	505.7	99.7	395.0	179.3	395.3	124.7	300.3*	193.6*	155.3	406.7	79.7	358.7	181.0	18.1
Mean	461.3	128.0	41.04	177.9	439.7	152.1	231.4	138.0	144.4	394.7	75.7	385.4	220.4	21.9
CD (P=0.0r)	76.4	37.1	72.6	32.7	42.2	27.4	33.0	25.6	24.9	37.1	18.5	29.0	44.3	3.8

* Significant at P=0.05

Table 2 *Per se* performance of plant part partitioning coefficients at different growth stages under terminal moisture stress environment in Indian mustard

Genotype	100 DAS					Harvest					H.I
	Root	Stem	Leaf	*Siliqua*	*Seed*	Root	Stem	Leaf	*Siliqua*	*Seed*	
Rajat	151.7	429.3	136.0	283.7	172.0	127.0	409.3	84.3	379.6	228.0	22.8
Rajat x PCR-10	135.7	375.7	150.0	339.3	210.0	103.0	406.3	82.0	408.3*	239.7	24.0
Rajat x DHR-9401	193.0	431.3	131.0	244.7	144.3	138.7	380.3	67.3	413.6*	254.0*	25.4*
Rajat x RH-30	170.3	428.7	167.3	233.7	150.7	162.3	387.3	99.0*	351.3	223.3	22.3
Rajat x Varuna	138.0	453.7	132.7	275.7	165.3	118.7	379.3	68.3	433.0*	261.3*	26.1*
Rajat x BIO 902	155.7	415.3	151.7	278.0	184.0	111.3	379.0	72.7	436.3*	256.7*	25.6*
Rajat x RH 819	175.7	415.7	137.3	270.0	169.7	136.7	361.0	68.3	434.0*	272.3*	27.2*
Rajat x RH 8812	203.0	437.3	147.7	212.0	128.3	155.7	394.0	70.0	381.3	236.3	23.6
PCR-10	151.7	471.0	199.0	179.0	106.3	133.7	408.0	112.0*	346.3	171.0	17.1
PCR-10 x DHR-9401	165.7	331.0	230.0	269.3	149.3	173.7	340.0*	119.7*	366.3	207.0	20.7
PCR-10 x RH 30	148.7	512.3	107.7	232.0	146.7	128.3	423.0	55.3	393.0	214.6	21.5
PCR-10 x Varuna	174.3	450.3	166.3	209.3	122.0	146.0	409.0	72.6	372.0	183.0	18.3
PCR-10 x BIO 902	153.0	426.7	158.7	262.0	162.3	128.7	386.0	73.0	412.0*	219.3	21.9
PCR-10 x RH 819	145.3	484.3	160.3	201.0	123.7	148.7	401.7	101.7*	348.3	197.3	19.7
PCR-10 x RH 8812	22003	302.7	190.3	287.0	164.7	180.3*	381.0	109.3*	329.3	166.7	16.7
DHR-9401	122.7	449.7	140.7	286.7	187.7	137.7	389.0	72.3	400.7	206.7	20.7
DHR-9401 x RH 30	152.0	466.0	159.0	223.3	124.3	152.3	404.3	87.3	356.3	206.0	20.6
DHR-9401 x Varuna	182.7	353.7	174.7	289.0	164.7	179.7*	396.3	92.0*	332.0	167.0	16.7
DHR-9401 x BIO 902	188.3	303.7	132.0	376.0	216.7*	183.0	391.7	69.3	356.0	201.3	20.1
DHR-9401 x RH 819	118.3	451.0*	145.7	285.3	183.3	125.7	463.0*	65.3	346.3	190.3	19.0
DHR-9401 x RH 8812	201.0*	345.7	144.3	309.7	170.7	187.7*	315.3	80.3	416.7*	216.0	21.6
RH 30	127.3	361.0	138.7	373.3*	240.7*	136.7	393.3	96.3*	373.7	237.0	23.7
RH 30 x Varuna	146.0	389.3	115.3	343.0*	216.3*	146.6	406.3	58.7	388.0	245.7*	24.5*
RH 30 x BIO 902	170.0	405.7	141.7	282.0	165.0	148.6	394.6	60.3	396.3	220.0	22.0
RH 30 x RH 819	201.0*	373.3	84.7	341.3*	224.0*	168.0	426.7*	42.3	362.6	208.3	20.9
RH 30 x RH 8812	165.3	421.7	137.0	256.0	158.0	152.6	372.0	68.0	407.3*	229.0	22.9
Varuna	183.7	380.7	134.7	301.0	176.3	160.3	407.7	85.7	347.0	189.7	19.0
Varuna x BIO 902	147.0	445.0*	98.3	310.0	195.3	134.7	408.0	54.7	402.7	196.3	19.6
Varuna x RH 819	175.3	354.0	151.3	320.0	189.0	164.7	355.6	68.0	411.7*	234.3	23.5
Varuna x RH 8812	175.7	433.3*	129.7	261.0	156.7	145.7	399.0	81.7	373.7	199.3	19.9
BIO 902	215.7*	335.3	115.3	301.3	208.3	159.0	451.3*	65.7	323.7	194.0	19.4
BIO 902 x RH 819	183.0	335.3	96.0	386.0*	245.7*	192.3*	393.3	62.0	352.3	194.0	19.4
BIO 902 x RH 8812	140.7	403.7	115.0	341.0*	207.6	127.7	384.7	60.3	426.7*	236.3	23.6
RH 819	267.3*	352.7	170.3*	209.6	138.3	236.0*	416.0	81.7	266.7	149.3	14.9
RH 819 x RH 8812	143.3	[illegible]	119.6	359.7*	205.3	119.3	511.7*	49.3	319.3	174.3	17.4
RH 8812	159.3	354.7	113.3	370.0*	244.3*	151.7	401.3	79.3	367.3	201.7	20.2
Mean	169.1	402.5	142.3	286.2	175.1	150.1	3987.0	76.0	375.8	211.9	21.2
CD (P=0.0r)	24.5	28.6	19.4	48.3	38.4	28.6	28.4	15.8	30.7	32.3	3.2

* Significant at P=0.05

At harvest, the seed partitioning coefficient was observed higher under normal environment as compared to terminal moisture stress condition. This indicated that these plant parts at their respective growth interval were chief source of photosynthates.

In general, the maximum partitioning coefficient was recorded in stem followed by siliqua, seed, root and leaf at 100 DAS under terminal moisture stress and at harvest under both the environments. The results obtained by Pannu *et al.*, (1997) are in the line of present studies. Whereas, at 100 DAS under normal environment, the highest partitioning coefficients was observed in stem followed by siliqua, leaf, root and seed.

Root partitioning increased upto 50 DAS and declined thereafter until harvest under both the environments as also reported by Pannu *et al.*, (1997). At 50 DAS the highest and lowest root partitioning coefficients were recorded in the varieties RH 30 x RH 8812 and BIO 902 x RH 8812, respectively. Whereas, maximum value of stem and leaf partitioning coefficients were recorded in Rajat x DHR 9401 and Rajat x RH 819, respectively.

At 100 DAS and harvest, the highest root partitioning coefficient was recorded in genotype RH 819 under both the environments. Under normal environment and terminal moisture stress environment, the highest stem partitioning coefficient was observed in RH 30 x BIO 902 and PCR 10 x RH 30,I respectively. However, the genotype PCR 10 x RH 8812 observed poorest for their stem partitioning coefficient under both environments. The genotype PCR 10 x DHR 9401 recorded highest leaf partitioning coefficients at 100 DAS and harvest under both the environments. Rajat x PCR-10 and BIO 902 x RH 819 recorded highest siliqua partitioning coefficients at 100 DAS under normal and terminal moisture stress environments, respectively.

At harvest, the terminal moisture stress reduced stem partitioning coefficient more than that of the root partitioning. Present findings are in conformity with Pannu *et al.* (1992). The genotype RH 819 x RH 8812 recorded highest stem partitioning coefficients under both the environments. Siliqua partitioning coefficient was recorded highest in BIO 902 x RH 8812 and Rajat x BIO 902, under normal and terminal moisture stress environments, respectively. However, stem and siliqua partitioning coefficients were observed nearly equal at harvest as also observed by Patil *et al.* (1997). Genotype Rajat x RH 819 recorded highest seed partitioning coefficient and harvest index at harvest under both the environments, indicating the highest mobilization of assimilates from source to sink.

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Genetic diversity analysis in Indian mustard, *Brassica juncea* L. Czern & Coss using RAPD markers

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Abstract

Genetic diversity among 45 genotypes of *Brassica juncea* including released varieties, mutants, *advanced breeding material and single plant* selections was estimated using 37 decamer primers of the 80 initially screened. A total of 205 amplicons were obtained with the average of 5.54 bands/primer, of these 162 were found to be polymorphic and the level of polymorphism was 79.02%. The number of bands generated was more primer dependent than the genotype and ranged from 1-19. Though all the genotypes were discriminated in the present study still the identification of such a large number of genotypes was not possible with limited number of primers. A few of the primers generated variety specific bands for only a limited number of genotypes. Jaccard's pair-wise similarity coefficient values for 45 genotypes were calculated and the range of genetic similarity was found to be 0.60 to 0.97 with the average of 0.791 ± 0.002. A dendrogram was generated by UPGMA cluster analysis based on Jaccard's similarity coefficients, which showed poor grouping of the genotypes since the similarity among the varieties, and groups were comparable. Genotypes were grouped as per their pedigree or origin.

Key words: Indian mustard, RAPD, primers, polymorphism, similarity coefficient

Introduction

Oilseed Brassica occupy an important position in the rainfed agriculture of India and is second in importance after groundnut. Of the different types of oleiferous Brassicaceae, Indian mustard [*Brassica juncea* (L) Czern & Coss] predominates in India. For any crop improvement program, analysis of genetic diversity is the first and foremost step. Information on genetic diversity or relationships among accessions within and between species has several important applications for crop improvement. The estimates of genetic relationships can be useful for organizing germplasm for the identification of cultivars, assisting in the selection of parents for hybridization and reducing the number of accessions needed to ensure sampling of a broad range of genetic variability. Polymerase Chain Reaction (PCR)-based molecular markers is a powerful tool to analyze genetic relationships and diversity among genotypes. Random amplified polymorphic DNA (RAPD), first reported by Williams *et al.* (1990) is one such PCR based tool. Recently, RAPD analysis has been used for diversity analysis in *Brassica* oilseeds (Mailer *et al.*, 1994; Qiao *et al*, 1998 and Das *et al*, 1999). Therefore, the present study was under taken to evaluate genetic relationships among 45 different genotypes of *B. juncea* by employing RAPD..

Materials and methods

Forty-five genotypes including released varieties, mutant lines, advance breeding lines and single plant selections were grown at Plant Biotechnology Centre, Rajasthan Agricultural University, Bikaner. These genotypes possessed some of the desirable traits of economic importance like higher oil content, white rust resistance and earliness. For each genotype, 5 g of young leaves from 15-20 seedlings were taken for DNA extraction using the CTAB method suggested by Sagahai Maroof *et al.* (1984) with some modifications. The extract was treated with RNAase to degrade the RNA, quantification and quality checking was done by 0.8% agarose gel and by recording optical density at 260 and 280 nm by spectrophotometer. A total of 37 decamer primers (Operon Technologies, Inc., U.S.A.) were selected for final RAPD-PCR analysis. Each reaction mixture (25µl) for P..R amplification consisted of 50 ng of template DNA, 200 µM of each dNTPs (Banglore Genei, India), 0.2 µM decamer primer (Operon Technologies), 0.5 U Taq DNA polymerase and 1x reaction buffer containing 15 mM $MgCl_2$ (Banglore Genei, India). The thermocycler (Biometra) was operated

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for one cycle at 92°C for 5 min. and then programmed for 44 cycles of 92°C for denaturation (1 min.), 37°C for primer annealing (1 min.) and 72°C for elongation (2 min.). It was followed by a final amplification step of 72°C (5 min.). The amplified products were electrophorased on 1.5% agarose gel at 50 volts in 1x TBE buffer. The gel was stained in the presence of ethidium bromide and photographed under UV light.

For all the genotypes, bands on RAPD gels were scored as present (1) or absent (0) and missing and doubtful cases were scored as '2'. Pair-wise association coefficients were calculated from qualitative data matrix using Jaccard's similarity coefficient. The matrix was subjected to Unweighted Pair-Group Method for Arithmetic Averages Analysis (UPGMA) to generate a dendrogram using the NTSYS-pc software developed by Rohlf (1993).

Results and discussion

Selection of these 37 primers was done on the basis of their multibanded and easily scorable amplification products. A typical example with primer OPC-9 is shown in Fig. 1. Total 205 amplicons were obtained with these 37 primers with the average of 5.54 bands per primer. The number of bands generated was more primer dependent than genotype and ranged from 1(OPA-5) to 19(OPA-10). Out of these 205 bands, 162 were found to be polymorphic and the level of polymorphism was 79% (Table 1). Two primers from OPC series and five primers each from series OPA, OPB and OPG showed 100% polymorphism, while two primers namely, OPG-4 and OPG-8 did not show any polymorphism. Primer, OPA-5 was found to be monomorphic as it gave a single band. Various authors have also reported the variations in total bands produced and level of polymorphism generated (Mailer *et al.*, 1994; Qiao *et al.*, 1998; Das *et al.*, 1999).

All the 45 genotypes have been discriminated in the present RAPD analysis involving 37 decamer primers. Though it is difficult to prepare a key for identification of all the genotypes on the basis of polymorphism involving a small set of primers, a few of the primers have generated variety specific bands for only a limited number of genotypes. The most diverse genotype CS-52 had the maximum number of primer specific bands. This suggested that limited number of random primers would not identify large number of varieties with relatively low level of variation. Earlier studies with limited number of varieties have reported efficient identification with a few primers, in *Brassica juncea* (Qiao *et al.*, 1998) and in *Brassica napus* (Mailer *et al.*, 1994).

Jaccard's pair-wise similarity coefficient values for 45 genotypes were also calculated. The range of genetic similarity was found to be 0.60 (CS-52 and SPS-3) to 0.97 (Varuna and Bio-902) with an average of 0.791±0.002. The average genetic similarity among the groups A, B, C, D and E was found to be 0.910 ± 0.006, 0.845 ± 0.013, 0.823 ± 0.004, 0.804 ± 0.012 and 0.782 ± 0.009, respectively. In the present study, the groups 'D' and 'E' were found to be most diverse, as the group 'D' has the genotypes with diverse origin, like BEC-114 (exotic and small seeded) and RB-9901 (tetralocular, seems to be a inter-specific cross). The group 'E' had its origin through wide hybridization with *Brassica napus*. The group 'A' (released varieties) had shown maximum similarity as these varieties have the common parent, Varuna in their ancestry. It also reflected the tendency of breeders to use well-established high yielding variety in their breeding program. High similarities have also been reported by many authors among the genotypes related by ancestry (Mailer *et al.*, 1994; Qiao *et al.*, 1998; Das *et al.*, 1999).

A dendrogram was generated by UPGMA cluster analysis based on Jaccard's similarity coefficients (Fig. 2). Over all view suggests that grouping of the genotypes is very poor as the similarity among the varieties and groups were comparable. Still varieties like Varuna and its derivative Bio-902 (somaclonal variation) have been put very close with maximum similarity of 97%. The genotypes having Varuna in their parentage were clustered at approximately 90% level of similarity and all the other genotypes were put to two major clusters within 10% less similarity, i.e., at 80% similarity level except SPS-9, RSM-9821 and CS-52. The genotypes developed at Sriganganagar and Mandor (Jodhpur) had higher variation among them. BEC-114, an exotic collection clustered with Mandor group at a relatively low level of similarity (85 %) reflecting its resemblance to Indian material. HEB-3 (Varuna x Yellow seeded mutant) where yellow seeded mutant could have been either a napus variety or a derivative of wide hybridization involving *B. napus* since it is showing more resemblance to *B. napus* derivatives. It could be the reason of resemblance of RB-9901 (tetralocular) to group 'E'.

Genotype developed at BARC, Trombay (Tm) are either direct mutants from diverse parents or have been crossed to diverse parents to improve further, which is reflected in their distribution among other groups. The material in-group 'C' consists of single plant selections for specific purposes, mainly resistance against white rust. The selections in this group were from diverse sources, which are reflected in their poor clustering and presence of highly diverse genotype like SPS-9. The genotype CS-52 selection for salinity tolerance was found to be most diverse having 67.2% average similarity with other genotypes. It suggested that material bred for different conditions or involving wide hybridization was more diverse than the material developed for normal conditions.

Table 1 **Primers, their sequences and level of polymorphism detected by them**

Primer	Sequence (5'-3')	Total bands	Polymorphic bands	Polymorphism(%)
OPA-1	CAGGCCCTTC	5	5	100.0
OPA-2	TGCCGAGCTG	3	3	100.0
OPA-3	AGTCAGCCAC	6	6	100.0
OPA-5	AGGGGTCTTG	1	1	100.0
OPA-7	GAAACGGGTG	3	3	100.0
OPA-8	GTGACGTAGG	6	4	66.7
OPA-9	GGGTAACGCC	8	4	50.0
OPA-10	GTGATCGCAG	19	16	84.1
OPA-11	CAATCGCCGT	11	8	72.7
OPB-1	GTTTCGCTCC	5	4	80.0
OPB-5	TGCGCCCTTC	5	1	20.0
OPB-6	TGCTCTGCCC	8	8	100.0
OPB-10	CTGCTGGGAC	7	2	28.6
OPB-13	TTCCCCCGCT	3	3	100.0
OPB-14	TCCGCTCTGG	5	5	100.0
OPB-15	GGAGGGTGTT	6	5	83.3
OPB-16	TTTGCCCGGA	4	4	100.0
OPB-17	AGGGAACGAG	4	1	25.0
OPB-18	CCACAGCAGT	7	7	100.0
OPB-19	ACCCCCGAAG	7	7	100.0
OPB-20	GGACCCTTAC	3	2	66.7
OPC-1	TTCGAGCCAG	8	7	87.5
OPC-2	GTGAGGCGTC	4	3	75.0
OPC-3	GGGGGTCTTT	4	4	100.0
OPC-4	CCGCATCTAC	7	6	85.7
OPC-6	GAACGGACTC	7	7	100.0
OPC-09	CTCACCGTCC	6	4	66.7
OPG-1	CTACGGAGGA	4	3	75.0
OPG-2	GGCACTGAGG	5	5	100.0
OPG-3	GAGCCCTCCA	4	4	100.0
OPG-4	AGCGTGTCTG	2	0	00.0
OPG-7	GAACCTGCGG	4	4	100.0
OPG-8	TCACGTCCAC	3	0	100.0
OPG-15	ACTGGGACTC	6	6	100.0
OPG-16	AGCGTCCTCC	4	4	100.0
OPG-18	GGCTCATGTG	3	2	66.7
OPG-19	GTCAGGGCAA	8	4	50.0
	Total	205	162	79.0

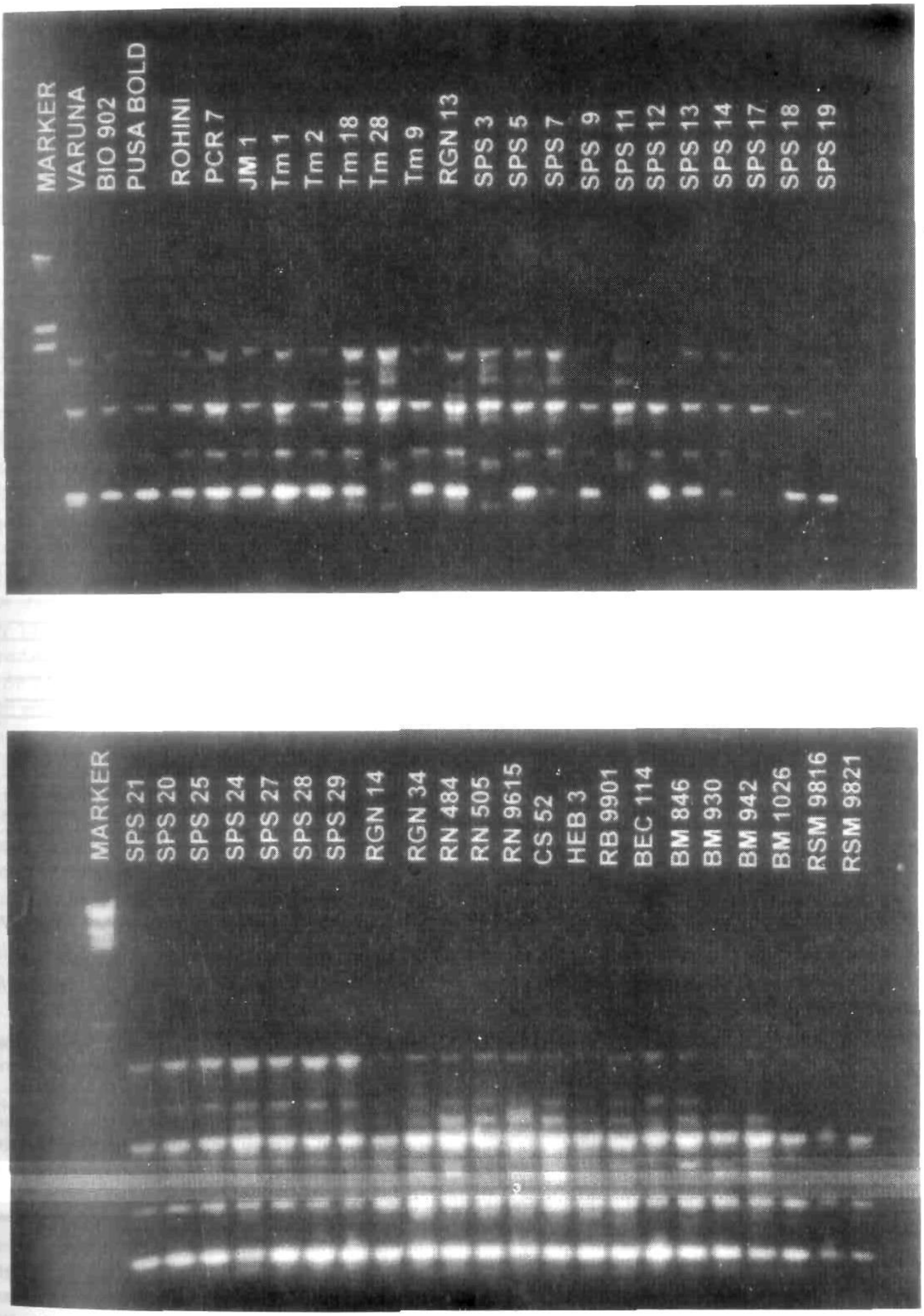

Fig. 1 RAPD profile of 45 genotypes of Indian mustard obtained with primer OPC-9

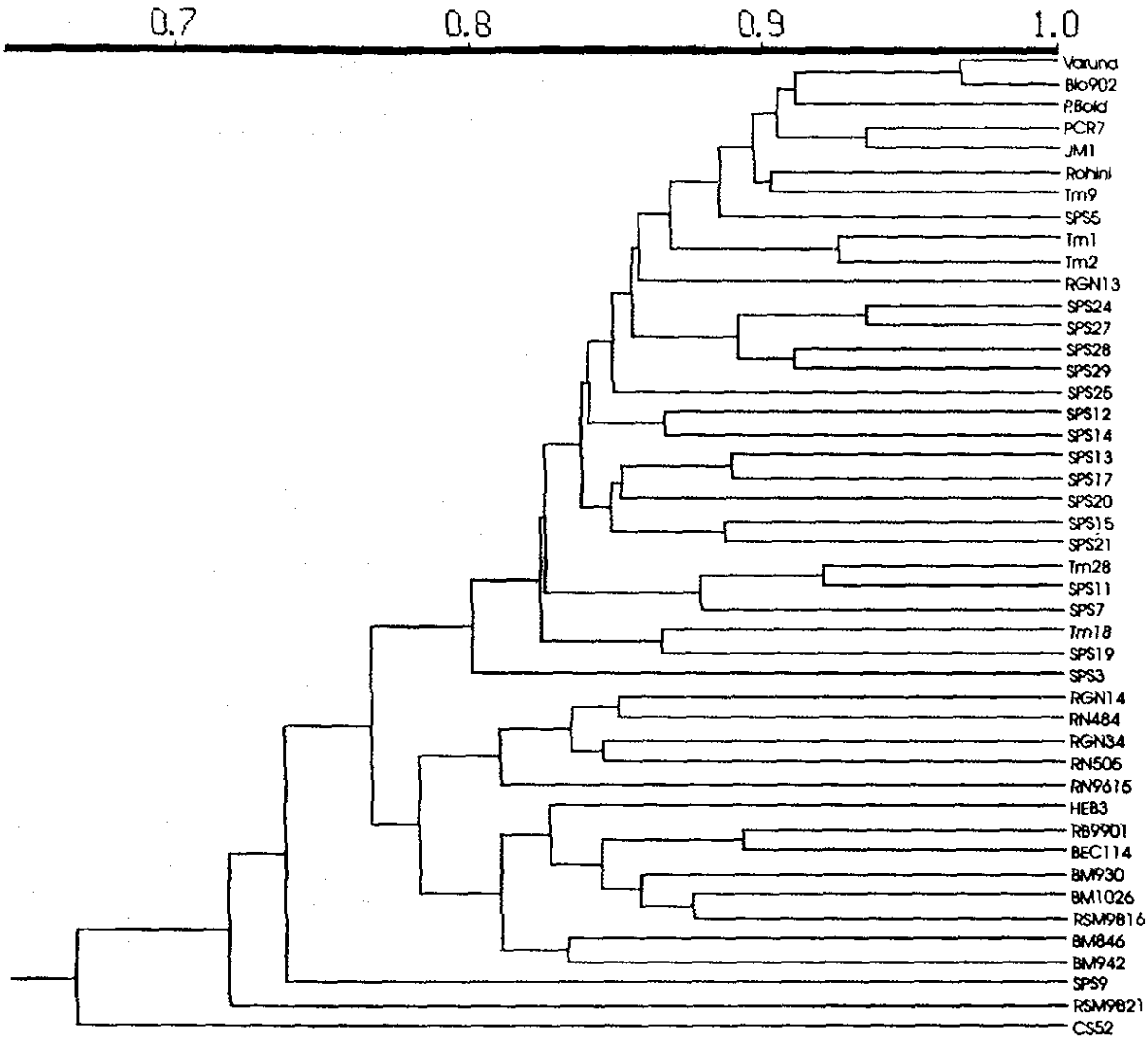

Fig. 2 Dendrogram showing relationships among *Brassica juncea* genotypes generated by UPGMA analysis based on RAPD markers

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Response of rapeseed and mustard varieties at different sowing dates

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Abstract

A field experiment was conducted to study the performance of promising varieties of rapeseed and mustard (Kranti, Urvashi, Hyola-401, GSL-1, Kiran and NDYS-2) under different sowing dates (September 30, October 15; 30 and November 15) in *Tarai* conditions of Uttaranchal during the winter *(rabi)* season of 2000-01 and 2001-02. Significantly more branches/plant, seeds/siliqua, 1000-seed weight and seed yield were recorded in case of September 30 sowing. Subsequent delay in sowing i.e., October 15, 30 and November 15 resulted in reduced seed yield of rapeseed and mustard by 13.2, 35.0 and 47.8% during 2000-01 and 11.7, 27.6 and 45.5% during 2001-02, respectively. With respect to oil content, the September 30 sown crops remained at par with October 15 during 2001-02 and resulted in significantly higher oil content over later sowing dates during both the years. Delayed sowing increased protein and glucosinolate content. Among the varieties, significantly higher branches/plant, siliquae/plant, seed yield and glucosinolate content in Kiran, seeds/plant in Hyola-401 and 1000-seed weight in Urvashi were recorded during both the years. Maximum protein (%) and oil (%) were resulted in NDYS-2 and Hyola-401, respectively. Significantly lower glucosinolate content was recorded in Hyola-401.

Key words: Sowing dates, rapeseed and mustard, varieties, yield attributes, seed yield

Introduction

Traditional practices of rapeseed-mustard cultivation are still prevailing in *Tarai* regions of Uttaranchal and Uttar Pradesh causing low seed and oil yield (Yadav and Yadav, 1997). The optimum time of sowing and selection of suitable varieties play an important role in boosting the seed yield of rapeseed-mustard. Delay in sowing suffers due low existing temperature at early stage, which consequently affects crop germination and establishment and suffers due to heavy aphid infestation. Therefore, sowing of crop at appropriate time is an important non-cash input for boosting crop productivity (Shastry and Kumar, 1981; Rajput *et al.*, 1991; Singh *et al.*, 2001). Use of high yielding varieties is also an important factor, responsible for higher yield. The present study was, therefore, conducted to find out appropriate sowing time and suitable varieties of rapeseed and mustard under *Tarai* region of Uttaranchal and Uttar Pradesh.

Materials and methods

The study was conducted at Crop Research Centre of G.B. Pant University of Agriculture and Technology, *Pantnagar*, U.S. Nagar, Uttaranchal during winter seasons of 2000-01 and 2001-02 to evaluate the most suitable variety of rapeseed and mustard and optimum sowing time. The experimental soil was loam with soil pH 7.2, organic carbon 1.07% and available phosphorus 19.1 kg/ha. The crop was sown in Split Plot Design with three replications. The treatments comprised 4 sowing dates (September 30, October 15, 30 and November 15) in main plots and 6 varieties (Kranti, Urvashi of *B. juncea*, Hyola-401, GLS-1 of *B. napus*, Kiran (PBC-922) of *B. carinata* and NDYS-2 of *B. campestris* var. yellow sarson) in sub-plots. An uniform basal dose of 60 kg nitrogen, 60 kg P_2O_5 and 20 kg K_2O was applied at the time of sowing. Remaining 60 kg nitrogen was topdressed in two equal splits at the time of first and second irrigation, respectively. The crop was sown at 30 cm row spacing using 5 kg seeds/ha. The weather conditions, in general, were more favourable during 2000-01. Observations on yield attributes, yield and quality were recorded at the time of harvest.

Results and discussion

Effect of sowing dates: The seed yield and yield attributing characters of rapeseed and mustard were significantly influenced by sowing dates, except siliqua/plant which remained at par during 2001-02 (Table 1 and 2). Crop sown on September 30 enhanced significantly all yield contributing characters i.e., branches/plant, seeds/siliqua and 1000 seed weight and seed yield over the other sowing dates during both the years, but siliqua/plant remained at par with November 15 sown crop during 2000-01. The highest seed yield of 1740 and 1432 kg/ha during 2000-01 and 2001-02, respectively, were recorded with September 30 sown crop and showed an increase of 15.2, 53.8 and 91.4% during 2000-01 and

13.3, 38.1 and 83.54% during 2001-02 over the yield obtained by the sowing in October 15, 30 and November 15, respectively. Delay in sowing (from September 30 to November 15) declined yield attributing characters as well as seed yield. This may be attributed basically to the reason that early sown crop received optimum environmental conditions required for better crop growth and yield attributing parameters. While, delay in sowing could not get favourable environmental conditions, which affected yield contributing parameters with the concomitant effect on seed yield. Longer reproductive phase in early sowing might have resulted in these differences in seed yield. Rajput *et al.* (1991), Yadav and Yadav (1997) and Singh *et al.* (2001) also reported similar results.

The oil content decreased but protein and glucosinolate content increased with delayed sowing from September 30 to November 15 during both the years (Table 3). The September 30 sown crop recorded significantly higher oil content over other sowing dates, except October 15 which was at par during 2001-02. However, significantly lower oil content was recorded in November 15 sowing. The oil content in seed was higher in early sowing might be due to the fact that seed in late sown crop did not develop fully and diversion of photosynthates into protein which resulted lower oil content (Norton and Harris, 1975). The glucosinolate content was significantly higher in November 15 sown crop but remained at par with October 30 sowing during 2001-02. High temperature prevailed during seed developmental stage of November 15 sowing crop. Higher temperature plays vital role in glucosinolate development profile, because of decrease in dilution (Eaton, 1942).

Effect of varieties: Varieties differed significantly with respect to yield and yield attributing characters during both the years (Table 1 and 2). Variety Kiran recorded significantly higher branches/plant and siliqua/plant which resulted in significantly higher seed yield over other varieties. However, significantly higher seeds/siliqua in NDYS-2 and 1000-seed weight in Urvashi were recorded during both the years. It might be due to genetic characteristics of the particular varieties. The variety Kiran recorded significantly higher seed yield over other varieties might be due to longer duration of the crop and more siliqua/plant. The significantly lower seed yield was recorded in variety NDYS-2 during both the years. The varietal differences of yield and yield attributes were also reported by Singh *et al.* (1996) and Singh *et al.* (2001).

Table 1 Seed yield (kg/ha) of rapeseed and mustard varieties as influenced by sowing dates

Sowing date (D)	Variety (V)													
	2000-01							2001-02						
	Kranti	Urvashi	Hyola-401	GSL-1	Kiran	NDYS-2	Mean	Kranti	Urvashi	Hyola-401	GSL-1	Kiran	NDYS-2	Mean
September 30	1736	1904	1835	1735	2153	1078	1740	1402	1568	1395	1476	1840	913	1432
October 15	1571	1736	1428	1622	1865	845	1511	1250	1377	1210	1463	1577	707	1264
October 30	1059	1105	1202	1326	1428	666	1131	1064	1028	999	1178	1337	417	1037
November 15	833	863	1010	1082	1290	378	909	772	827	840	920	1008	320	781
Mean	1300	1402	1369	1441	1664	742		1122	1200	1111	1259	1440	589	
					SEm±	CD (P=0.05)						SEm±	CD (P=0.05)	
Sowing dates					33	116						22	77	
Varieties					35	100						27	77	
Interaction														
To compare V at same D					73	209						56	160	
To compare D at same or different V					72	216						54	160	

Table 2 Effect of sowing dates and varieties on yield attributes of rapeseed and mustard

Treatment	Branches/plant		Siliqua/plant		Seeds/siliqua		1000-seed weight (g)	
	2000-01	2001-02	2000-01	2001-02	2000-01	2001-02	2000-01	2001-02
Sowing dates								
September 30	22	18	1201	178	18	16	4.4	4.2
October 15	20	16	1197	167	16	16	4.1	3.8
October 30	17	14	175	170	15	15	3.5	3.3
November 15	14	12	171	163	14	13	3.2	3.0
SEm±	0.30	0.40	5.80	4.0	0.20	0.10	0.05	0.04
CD (P=0.05)	1.1	1.2	20.1	NS	0.6	0.30	0.2	0.1
Varieties								
Kranti	18	11	215	208	12	11	3.9	3.7
Urvashi	17	11	206	186	11	11	4.6	4.4
Hyola-401	9	8	131	128	21	20	3.4	3.2
GSL-1	12	10	219	215	14	14	2.9	2.7
Kiran	54	47	277	226	12	11	4.3	4.2
NDYS-2	5	4	66	55	24	23	3.7	3.5
SEm±	0.6	0.60	5.70	6.10	0.20	0.20	0.04	0.06
CD (P=0.05)	1.7	1.6	16.2	17.7	0.6	0.6	0.1	0.2

Table 3 Effect of sowing dates and varieties on quality of rapeseed and mustard

Treatment	Oil content (%)		Protein content (%)		Glucosinolate content (μ mole/g fat free meal)	
	2000-01	2001-02	2000-01	2001-02	2000-01	2001-02
Sowing dates						
September 30	40.9	40.1	21.3	21.8	69.2	71.3
October 15	39.5	39.3	21.6	22.1	75.4	74.5
October 30	37.7	37.7	22.0	22.4	81.3	80.5
November 15	36.0	35.6	22.5	22.8	86.2	83.5
SEm±	0.2	0.4	0.2	0.1	1.2	1.5
CD (P=0.05)	0.8	1.2	0.7	0.5	4.2	5.0
Varieties						
Kranti	37.7	37.1	22.3	22.6	85.9	89.1
Urvashi	38.1	37.5	22.0	22.4	87.8	85.3
Hyola-401	39.8	39.4	21.6	22.0	25.9	22.2
GSL-1	39.1	39.2	20.9	21.3	81.7	86.1
Kiran	37.8	37.3	21.8	22.3	98.0	97.5
NDYS-2	38.6	38.6	22.7	23.2	89.1	84.5
SEm±	0.3	0.4	0.2	0.2	1.5	1.4
CD (P=0.05)	0.9	1.0	0.6	0.5	4.2	4.1

Hyola-401 was the superior variety in respect to quality parameters which recorded maximum oil content and minimum glucosinolate content (Table 3). Variety Hyola-401 was at par with GSL-1 in both the years and GSL-1 and NDYS-2 during 2001-02 and recorded significantly higher oil content over other varieties. Significantly lower glucosinolate content was recorded in Hyola-401 compared to other varieties. It might be due to genetic characteristics of double low variety of Hyola-401, however, significantly higher protein content in seed was recorded in NDYS-2, but, was at par with Kranti during 2000-01. The varietal differences in respect to oil and protein content were also reported by Rajput *et al.* (1991).

Interaction between sowing dates and varieties was significant in relation to seed yield during both the years (Table 1). September 30 and October 15 sown crop produced significantly higher seed yield in variety Kiran over other varieties, except GSL-1 in October 15 sowing, which remained at par with Kiran during 2001-02. Under October 30 and November 15 sowing, variety Kiran remained at par with GSL-1 and produced significantly higher seed yield over other varieties during both the years. Variety NDYS-2 recorded significantly lower seed yield in all the sowing dates during both the years. From the above discussion, it could be concluded that early sowing (September 30) resulted in higher yield of rapeseed and mustard varieties. Sowing in November, a normal practice by the farmers was not congenial for rapeseed and mustard in *Tarai* region of Uttaranchal and Uttar Pradesh because of drastic reduction in seed yield and oil content. Kiran was the superior variety in respect to yield, but from quality point of view, the variety Hyola-401 was found superior over other varieties.

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

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Abstract

A field study was conducted during 2000-01 and 2001-02 at Indira Gandhi Agricultural University, Raipur to study the residual effect of organic and inorganic sources of nutrition to *kharif* rice i.e., no nitrogen, 100% recommended dose of N (100% RDN), 100% RDN + 5t FYM, 80% RDN + 3 t FYM, 100% RDN blended with FYM, 80% RDN blended with FYM, 60% RDN blended with FYM + *Azospirillum*, 100% RDN as Urea : FYM : Soil, 80% RDN blended with poultry manure and 60% RDN blended with poultry manure + *Azospirillum* (main plot) and direct effect of five such treatments *viz.*, no nitrogen, 50 and 100% RDN with or without blending with 3t FYM/ha (sub-plot treatments) on mustard, *Brassica juncea* (L.) Czern and Coss., cv.. Pusa bold in Split Plot Design with three replications. The plant height, number of primary branches, drymatter production, LAI, light interception by crop canopy and seed yield of mustard under residual effect of 100% RDN blended with FYM was fond to be significantly higher than other treatments. The seed yield under this treatment was 11.1 and 34.6% higher over the residual effect of 100% RDN + 5t FYM and 100% RDN, respectively. Direct application of 100% RDN blended with FYM also excelled in these characters and recorded 8.1% more seed yield than 100% RDN.

Key words: Blending, *Azospirillum*, light interception

Introduction

In high rainfall regions of eastern India, rice is commonly grown during rainy season. After rice, mustard is traditionally grown as a component of economically viable cropping system for higher crop productivity. Sustenance of the productivity of rice-based cropping systems necessitates the integrated use of organic, bio-organic and inorganic sources of nutrients (Sharma *et al.*, 2001). In practices, the nutrient management strategies adopted in one crop often influence the fertilizer needs of the succeeding crops due to carry over effect of nutrients, which is more significant under integrated nutrient management systems (Kumar and Tripathi, 1990). Moreover, urea being the principal nitrogenous fertilizer in rice growing areas, there is a need to study the residual as well as direct effect of organic and bio-organic blended urea on mustard crop grown after rice.

Materials and methods

A field experiment was conducted during *kharif* seasons of 2000 and 2001 at the Instructional Farm, Indira Gandhi Agricultural University, Raipur. The soil of experimental field was sandy loam in texture, neutral in reaction (pH 7.5), low in organic carbon (0.42%) and available N (190.0 kg/ha), medium in available P (13.2 kg/ha) and high in available K (315.5 kg/ha). Ten treatments *viz.*, no nitrogen, 100% recommended dose of N (100% RDN), 100% RDN + 5t FYM, 80% RDN + 3t FYM, 100% RDN blended with FYM, 80% RDN blended with FYM, 60% RDN blended with FYM + *Azospirillum*, 100% RDN as Urea : FYM : Soil, 80% RDN blended with poultry manure and 60% RDN blended with poultry manure + *Azospirillum* were applied to rice cv. Mahamaya in a Randomized Block Design with three replications. In the succeeding *rabi* seasons, the residual effect of *kharif* treatments (main plot treatments) and direct effect of five N management treatments *viz.*, no nitrogen, 50 and 100% RDN with or without blending with 3 tonnes FYM/ha (sub-plot treatments) were studied to mustard cv. Pusa bold in Split Plot Design with three replications.

In rice, the recommended dose of N was 100 kg/ha as urea and uniform application of P_2O_5 and K_2O @ 60 kg and 40 kg/ha as SSP and MOP, respectively. All P_2O_5 and K_2O were applied basally but N was applied in three equal splits at transplanting, tillering and PI stages. In 100% RDN + 5 t FYM and 80% RDN + 3t FYM as per the doses was incorporated one day before transplanting but in 100% RDN blended with FYM and 80% RDN blended with FYM for each split application, required quantity of N was blended with FYM @ 1 t/ha, followed by incubation for 48 hours prior to application. In 60% RDN blended with FYM

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+ *Azospirillum* @ 2 kg/ha was mixed with FYM only during basal application. In 100% RDN as Urea : FYM : Soil, these were blended for each split application by thoroughly mixing urea with equal weight of dried powdered soil and three times FYM followed by incubation for 48 hours prior to application. In 80% RDN blended with poultry manure urea was blended with 0.5 t/ha of poultry manure for each split application. In 60% RDN blended with poultry manure + *Azospirillum*, urea was blended with 0.5 t/ha poultry manure as in 60% RDN blended with FYM + *Azospirillum*. In mustard, blending of 50 and 100% RDN as urea was done with 1.5 t FYM/ha (fresh weight) during each split, applied basally and at 30 days after sowing (DAS). The blending technique followed was similar to *kharif* treatments. The recommended dose of N for mustard was 80 kg/ha and applied as per the treatments. A common dose of phosphorus and potassium were applied basally @ 40 kg P_2O_5 and 40 kg K_2O/ha through single super phosphate and muriate of potash, respectively. The FYM contained 11.2% C, 0.61% N, 0.19% P, 0.53% K, 18.2% moisture and poultry manure contained 26.5% C, 1.6% N, 0.66% P, 1.0% K, 14.6% moisture. Growth parameters such as plant height, number of branches, light interception by crop canopy, drymatter accumulation, days to 50 per cent flowering, as well as seed and stalk yields were recorded. Physiological parameters like LAI, leaf area duration (LAD), thermal requirement for flowering (growing degree days) and harvest index (HI) were computed. Growing degree-days were calculated by simple arithmetic accumulation of daily mean temperatures above a base temperature. The base temperature for mustard is 5°C (Singh *et al.*, 1995).

Results and discussion

Plant height, number of primary branches and drymatter production: The plant height, number of primary branches and drymatter production of mustard (Table 1) under residual effect of 100% RDN blended with FYM was found to be significantly higher during 2000-01 and in pooled data, while, during 2001-02, maximum plant height and primary branches were noted under 100% RDN + 5t FYM and 100% RDN blended with FYM, which proved superior to all others during the two years in pooled data (Table 1). The benefits of residual effect of integrated N on mustard might be due to the fact that certain portion of the nutrient applied to a crop in organic form may remain unutilized due to time required for the slow decomposable fraction to release its nutrients for crop utilization. Besides, the favourable modifications in physico-chemical properties of soil also increases more amount of nutrient retention, which is ultimately available for the growth and development of the succeeding crop. Similar findings were reported by Sharma *et al.* (1999). The direct application of 100% RDN blended with FYM resulted in the tallest plant, highest number of primary branches and maximum drymatter, though it remained statistically similar to 100% RDN for plant height in both the years, for primary branches and drymatter production for one year only. Application of urea blended with FYM might have helped in enrichment of the soil with N, P and K and also might have exhibited higher N use efficiency for which there is favourable effect of 100% RDN blended with FYM (Sharma *et al.*, 1999).

LAI, LAD and light interception: The LAI at 45 and 90 DAS, LAD (45-90 DAS) and light interception through mustard crop canopy revealed the superiority of residual effect of 100% RDN blended with FYM at both the stages during both the years as shown in pooled analysis (Table 1). This treatment was closely followed by 100% RDN + 5 t FYM. The residual effect of no nitrogen treatment resulted in the lowest LAI, LAD and light interception. In direct effect also 100% RDN blended with FYM recorded significantly higher LAI, LAD and maximum light interception as compared to the rest of the treatments. Since the chief function of N is cell multiplication, it might have resulted in higher LAI, LAD and consequently more of light interception. Similar observations were also reported by Bhagat and Soni (2000).

Days to flowering and thermal requirement: The 50% flowering stage under residual effect of 100% RDN + 5t FYM and 100% RDN blended with FYM were simultaneous and significantly delayed compared to all other treatments, except 80% RDN + 3t FYM, 80% RDN blended with FYM and 80% DN blended with poultry manure during the first year and as per pooled data and the former two treatments in second year only (Table 1). The 50% flowering was the earliest with no nitrogen treatment. In case of direct effect, the days taken for 50% flowering was significantly higher under 100% RDN blended with FYM during both the years. This corroborates earlier findings of Prakash *et al.* (2000) who observed delayed flowering with higher levels of fertilizer. Increased N availability might be due to reduced N losses by formation of organo-mineral complexes through exchange reaction (Prasad and Singh, 1992). Further, prolonged availability of nutrients due to its mineralization from organic sources might be the cause for extended vegetative growth i.e., delayed flowering. Accumulation of growing degree days (GDD) for flowering of mustard due to the residual and direct effects of various integrated N nutrition also exhibited a similar trend as that of days to 50% flowering. This is obviously true to the reason that higher the number of days, more will be the accumulated heat.

Table 1 Effect of organic and inorganic sources of nutrition on various traits of mustard (Pooled data of 2000-01 and 2001-02)

Treatment	Plant height (cm)	Primary branches/ plant at harvest	Drymatter accumulation at 90 DAS (g/plant)	LAI (45 DAS)	LAI (90 DAS)	Leaf area duration (45-90 DAS)	Light interception (75 DAS) (%)	Days to 50% flowering	TR (DD)	Seed yield (kg/ha)	Stalk yield (kg/ha)	HI (%)
Residual effect												
No N	139	5	13.4	3.2	0.8	90.2	56.0	41.9	643	883	2648	25.0
100% RDN	147	6	20.1	4.0	1.1	114.8	68.8	43.9	669	1333	3878	25.5
100% RDN + 5t FYM	163	7	24.7	4.6	1.3	133.0	80.8	47.6	716	1615	5046	24.1
80% RDN + 3t FYM	151	6	21.9	4.1	1.1	116.5	71.2	45.5	690	1434	4430	24.5
100% RDN blended with FYM	163	7	26.4	4.9	1.4	140.6	85.7	47.6	716	1794	5541	24.4
80% RDN blended with FYM	155	6	23.7	4.4	1.2	125.6	75.8	45.5	690	1561	4794	24.5
60% RDN blended with FYM + *Azospirillum*	149	6	20.3	4.1	1.1	116.7	69.6	44.3	675	1316	4086	24.3
100% RDN as Urea : FYM : Soil	150	6	20.4	4.1	1.1	117.7	70.2	44.3	675	1370	4015	25.4
80% RDN blended with poultry manure	148	6	21.2	4.1	1.1	117.0	71.6	45.0	684	1391	4283	24.4
60% RDN blended with poultry manure + *Azospirillum*	147	6	19.5	4.1	1.1	117.9	70.6	44.2	674	1283	3898	24.7
SEm±	2.2	0.10	0.4	0.1	0.02	2.6	1.7	1.0	8	34	82	0.43
CD (P=0.05)	6.4	0.29	1.3	0.3	0.06	7.8	5.0	2.9	24	100	245	NS
Direct effect												
No N	128	5	16.2	3.0	0.8	83.9	51.7	43.1	658	910	3065	23.0
50% RDN	150	6	20.5	4.0	1.1	113.1	70.4	45.0	683	1338	3981	25.1
100% RDN blended with FYM	152	6	21.3	4.2	1.2	119.7	72.7	45.0	683	1415	4175	25.4
100% RDN	161	7	23.3	4.7	1.3	133.3	80.3	45.8	693	1599	4867	24.8
100% RDN blended with FYM	165	7	24.5	5.1	1.4	144.9	85.1	46.2	699	1728	5221	24.9
SEm±	1.8	0.07	0.4	0.1	0.02	1.8	1.0	0.4	3	17	55	0.32
CD (P=0.05)	5.1	0.19	1.2	0.2	0.07	5.2	2.8	1.1	8	48	154	0.89

TR = Thermal requirement for flowering (growing degree days)
HI = Harvest index
Note: Data for individual years is not given, as it followed the same trend as in pooled data.

Seed yield, stalk yield and HI: Seed and stalk yield of mustard was significantly higher in plots receiving 100% RDN blended with FYM during *kharif* and remained statistically superior to all other treatments. As per pooled data, the seed yield under this treatment was 11.1 and 34.6% higher over the residual effect of 100% RDN + 5t FYM and 100% RDN, respectively (Table 1). However, the effect of 80% RDN blended with FYM and 100% RDN + 5t FYM were comparable, but significantly superior to 80% RDN + 3t FYM and 100% RDN. Direct application of integrated nitrogen treatments to mustard resulted in the highest seed yield under 100% RDN blended with FYM, which remained significantly higher to all other treatments. Based on pooled data, the yield under this treatment was 8.1% more than that of 100% RDN. However, direct application of 50% RDN blended with FYM produced significantly lower seed yield compared to 100% RDN. Superior performance of blending of inorganic N with FYM might be owing to reduced loss of N and its increased availability to crop by fixation of NH_4^+ion with humus present in FYM (Bellakki *et al.*, 1998). So also Jain and Sharma (2000) observed favourable effect of integrated N use over inorganic N in mustard. The harvest index due to residual effect of *kharif* treatments was observed to be non-significant, though, it remained significant in response to the treatments directly applied to mustard. In case of direct application it was found to be the highest in 50% RDN blended with FYM, which remained at par with all other treatments directly applied to mustard, except the no nitrogen treatment. Higher N availability might have favoured greater source-sink relation at appropriate period of grain filling stage resulting in higher yield.

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Response of Indian mustard, *Brassica juncea* (L.) Czern & Coss to phosphorus under saline water irrigation in semi-arid region of Rajasthan

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Abstract

A field experiment was conducted during rabi 2000-01 and 2001-02 to evaluate the response of Indian mustard, *Brassica juncea* to saline water irrigation and find out the phosphorus requirement. The seed yield of mustard significantly decreased with increase in salinity of irrigation water schedule mainly due to decrease in plant height, number of siliquae/plant and number of seeds/siliqua. However, it became obvious that if one saline irrigation is to be given it should be avoided as first irrigation (at the time of flowering) and may be opted for second irrigation. The agronomic efficiency could not improve in the plots where first irrigation was with saline water even if the second irrigation was non-saline. A linear response to phosphorus with respect to seed yield was noticed upto 60 kg P_2O_5/ha. Maximum phosphorus use and agronomic efficiency was obtained with 20 kg P_2O_5/ha over control.

Key words: Mustard, phosphorus, saline water irrigation, electrical conductivity

Introduction

Sustainability of mustard production in arid and semi-arid region of Rajasthan is faced with the challenge of underline saline ground water. Out of total ground water available in the state, 68% is of poor quality (Minhas and Tyagi, 1998). However, there are situations where only limited amount of non-saline surface water is available that may be used conjunctively. The crop growth, yield and nutrient use efficiency decreased with the use of poor quality of irrigation water (Chauhan *et al.*, 1988). The under ground saline water is characterized by predominance of either the SO_4 or Cl ions. Additional application of phosphorus improved the yields of groundnut (Minhas *et al.*, 1998). Information on phosphorus requirement of mustard under saline water irrigation, especially when used conjunctively with non-saline surface water, is lacking. Hence, study was undertaken to investigate the effect of levels of saline water irrigation and phosphorus on the seed yield and phosphorus use efficiency of mustard.

Materials and methods

A field experiment was conducted during *rabi* season of 2000-01 and 2001-02 at the National Research Centre on Rapeseed-Mustard, Bharatpur, Rajasthan. The soil of the experimental field was clay loam in texture having pH 8.0, available N and P 252 and 6.1 kg/ha, respectively. The organic carbon and electrical conductivity of 1:2 soil: water extract varied between 0.32% and 0.34% and 0.35 dS/m and 0.55 dS/m at soil depth of 0-15 cm and 15-30 cm, respectively. The experiment was laid out in a Split Plot Design with four replications using four combinations of non-saline and saline water (W_1- two irrigations with non-saline water, W_2- first non-saline and second saline irrigation, W_3- first saline and second non-saline irrigation, W_4- two irrigations with saline water) in main plot and four phosphorus levels (0, 20, 40 and 60 kg P_2O_5/ha) in subplot. The non-saline and saline water was having electrical conductivity of 2.9 and 19.9 dS/m and pH 7.7 and 7.4, respectively. Mustard variety RH-30 was sown on 26th and 25th October during 2000 and 2001, respectively. Half of nitrogen and whole phosphorus (as per treatment) was applied as basal and remaining nitrogen was top-dressed after first irrigation i.e., 35 days after sowing (DAS). The recommended package of practices of mustard were followed. Data on growth and yield attributes were recorded from five randomly selected plants (Table 1). Phosphorus uptake, its content in grain and stover was determined by Vanadomolybdate yellow colour method (Jackson, 1973). The data were statistically analyzed by using standard procedure. The phosphorus use efficiency was calculated as increase in its uptake over control and agronomic efficiency was estimated as increase in seed yield over control per kg of P_2O_5 applied.

Results and discussion

Effect of saline irrigation water: Qualities of irrigation water and phosphorus levels had a significant effect on seed yield of mustard during both the years of experimentation (Table 1). The effect was more pronounced in the second year, which might be due to the cumulative effect of salinity. Two irrigations with non-saline water recorded significantly higher seed yield of mustard during 2000-01 and 2001-02. In the first year, first irrigation with saline water (W_3) was worse as compared to second irrigation with saline water (W_2). Whereas in the second year the differences among these treatments were not significant, may be due to built-up of salinity. The yield decrease was mainly due to reduced plant height resulting into less number of siliquae/plant and 1000-seed weight. On an average, two irrigations with non-saline water recorded 14.4, 26.3 and 35.6% higher seed yield over W_2, W_3 and W_4, respectively. Since the yield reduction was more when first irrigation was with saline water as compared second irrigation, it is better to opt for first a non-saline irrigation at the early crop stage and second one as saline than vice versa.

Uptake of phosphorus was significantly higher when both irrigations were with non-saline water (W_1) as compared to other treatments and minimum uptake (Table 2) was recorded in treatments where both irrigations were saline (W_4).

The best agronomic efficiency of phosphorus was obtained in the treatments where only non-saline water was applied. The efficiency decreased in other treatments. However, it was better in the treatment where only second irrigation was saline than other two treatments.

Table 1 Effect of irrigation water quality and phosphorus levels on yield attributes and seed yield of Indian mustard

Treatment	Plant height (cm)		Siliquae/plant		Seeds/siliqua		1000-seed weight (g)		Seed yield (kg/ha)		Mean
	2000-01	2001-02	2000-01	2001-02	2000-01	2001-02	2000-01	2001-02	2000-01	2001-02	
Irrigation water											
W_1	132	126	168	173	12.6	11.7	6.3	6.1	1736	1316	1526
W_2	124	109	146	142	12.1	11.5	6	5.8	1500	1173	1337
W_3	124	113	125	132	11.8	11.1	5.6	5.3	1363	1053	1208
W_4	106	109	121	106	11.0	10.5	5.1	5.0	1203	1047	1125
CD (P=0.05)	12	12	6	22	0.7	0.5	0.2	0.2	125	131	113
Phosphorus levels											
0	117	108	101	104	11.4	11.2	5.7	5.4	1224	911	1068
20	119	112	127	117	11.8	10.9	5.8	5.6	1421	1095	1258
40	125	121	144	148	12.1	11.5	5.7	5.5	1537	1236	1387
60	126	125	187	186	12.6	12.2	5.8	5.6	1621	1348	1485
CD (P=0.05)	NS	7	7	18	0.4	0.3	NS	NS	84	82	78

W_1 = two irrigations with non-saline water
W_2 = first non-saline and second saline irrigation
W_3 = first saline and second non-saline irrigation
W_4 = two irrigations with saline water

Table 2 Effect of irrigation water quality and phosphorus levels on phosphorus use efficiency of mustard

Treatment	Phosphorus uptake (P_2O_5 kg/ha)		Mean phosphorus use efficiency	Mean agronomic efficiency of phosphorus (seed /kg of P_2O_5)
	2000-01	2001-02		
Irrigation water				
W_1	32.5	21.2	0.20	9.3
W_2	28.3	18.5	0.20	8.1
W_3	28.4	16.0	0.21	7.5
W_4	20.7	15.5	0.19	7.8
CD (P=0.05)	3.5	2.5	-	-
Phosphorus levels				
0	21.6	12.3	-	-
20	26.7	16.6	0.24	9.5
40	29.1	19.8	0.19	8
60	32.5	22.3	0.18	7
CD (P=0.05)	3.2	1.5	-	-

Effect of phosphorus levels: The phosphorus levels significantly affected the seed yield of mustard, siliquae/plant, and seeds/siliqua in both the years and also plant height in the second year. The linear response to phosphorus was observed upto 60 kg P_2O_5/ha. Application of 20, 40 and 60 kg P_2O_5/ha increased the seed yield by 17.8, 29.9 and 39.0% compared with no phosphorus, respectively. The results, thus, indicated that the requirement of phosphorus was more under saline irrigation water. This was probably due to higher fixation of P as insoluble compound in the saline environment and relatively smaller fraction becoming available to mustard plants. The application of 60 kg P_2O_5/ha significantly enhanced the phosphorus uptake over rest of P levels during both the years. The better effect of increased phosphorus level over the recommended dose on crop yield under saline water irrigation has also been reported by Chauhan *et al.*, (1991). Increasing level of P application increased its' uptake significantly and the effect was more pronounced in the second year. The phosphorus use efficiency was more (0.24) at lower levels of phosphorus application and decrease with subsequent increase in P levels. The maximum 9.5 kg seed of mustard/ kg of P_2O_5 was obtained with the application of 20 kg P_2O_5/ha. over control. Application of phosphorus seems to mitigate the adverse effects of salinity.

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Analysis of rapeseed-mustard seeds by near infrared reflectance spectroscopy for total oil content

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Abstract

Present study was aimed to evaluate the performance of different calibration equations in the analysis of rapeseed-mustard seeds for their total oil content. Calibration equation was developed from four calibration sets of the samples which differ besides population, the crop year in which they were grown, average moisture level as well as physical morphology of the seeds. Regression statistics of the equations were compared to study the effect of math treatments, regression mode and presence of undesirable samples that give high residual value during equation development. Performance of the equations involving different calibration files as external validation sets was also studied. Finally, first derivative equation developed by stepwise regression mode with dried samples (average moisture level of 3%) from 2000-2001 crop year was selected for its wider application in predicting oil content of commonly grown rapeseed-mustard samples within the total oil content range from 27.87-53.08%.

Key words: Rapeseed-mustard, germplasm, oil content

Introduction

Development of analytical technique for rapid, comparative and accurate estimation of quality traits has always been a challenging task in the field of quality study of agricultural and food products. For example total oil content determination of an oilseed by an Official Soxhlet Extraction method takes about 8-12 hours. Introduction of nuclear magnetic resonance (NMR) technique (Conway and Earle, 1963; Madsen, 1976) though has reduced the analytical time, but not enough to meet today's research and market requirements. This is because wide line NMR analysis requires a minimum of 3-4 hours time to dry seeds to bring their moisture level to about less than 3%, to nullify its effect on oil value. Moreover, being a unitrait technique, its application is getting replaced by other techniques like NIRS (Near Infrared Reflectance Spectroscopy).

NIRS is a multi-trait technique that fulfills most of the requirements for rapid, reliable and cost effective screening for several quality traits of intact seed (Tkachuk, 1981; Tkachuk and Kuzina 1982; Van Deynze and Pauls, 1994; Daun and Williams, 1995; Velasco *et al.*, 1997a; Velasco and Becker 1998a;1998b) However, the technique has been considered an empirical method because calibration equations have to be obtained prior to routine analysis.

Development and selection of calibration equation has been a continuous process. Calibration results are influenced by many variables including the number of samples selected, sample presentation, primary method accuracy, instrument precision and particle size distribution (Holman and Edmondson, 1956). The statistical selection criteria explained by different workers help the process, but misuse of the computation powers routinely available with modern NIR instruments though produces very good statistical values, but the final equation will not be nearly as accurate as it appears. Chemical knowledge about the constituents and familiarity with the NIR/NIT (Near Infrared Transmittance) application allow the user to determine optimal wavelength selection and give greater confidence that NIR/NIT method is directly predicting the constituents of interest.

Though it has been in general conclusion as emerged from different studies (Velasco *et al.*, 1997b), that particular equation would perform better if it is developed from calibration set with large variability for interested parameter, and good repeatability in the analysis by the reference method. However, clear information is not available about the comparative performance of the equations when they are developed from calibration sets, which are different with respect to moisture level of the samples, their physical morphology and the environments in which samples are grown.

The objective of the present study is to select a general calibration equation for quantification of oil content in all types of rapeseed-mustard samples by using NIR technology.

Materials and methods

A total of 727 rapeseed-mustard collections from major species, namely *Brassica juncea*, *B. napus*, *B. rapa*, *B. carinata*, *B. nigra* and *Eruca sativa* were used in the present study. *These include 250 collections grown during* 1998-99 at Issapur Experimental Farm of NBPGR, New Delhi and another 477 collections that were grown in 2000-01. With these collections, the following four calibration sets were made for developing different NIR equations for the analysis of rapeseed-mustard samples for their oil content determination. The reference oil value are established by standard Soxhlet extraction method for all the sets:

Calibration set I : Selected samples from 1998-99 grown crop with the oil percentage range of 32.13-46.83% . average moisture of 8.5%.

Calibration set II: Contains the same samples but were scanned at ground state.

Calibration set III: Contains another set of samples from *2000-01 grown crop with the oil percentage range* of 27.42-51.31%, average moisture of 8.5%.

Calibration set IV: Contains same lot of samples as in calibration set III but samples were scanned at average moisture level below 3% after adjusting the radio frequency, audio frequency gain and gate width values and with the calibration of the instrument with pure oil of rapeseed extracted by Soxhlet method.

Validation set : Contains 259 whole seed samples from *rabi* 2002-03 grown crop with oil percentage range from 30.87-49.66%, established both by NMR and Soxhlet extraction method. This set was used as an external validation set to test the performance of the equations.

NIR reflectance spectroscopy: About 5g intact seed or equal volume of ground seeds were uniformly placed in a small ring cup (φ 3.8 cm) for scanning on a Monochromator NIR Systems Model TR-3712-6 (Foss Tecator Near Infrared Analyzer Systems: Silver Springs MD 20904, USA) and reflectance spectra (Log 1/R) from 400 to 2500 nm were recorded at 8 nm interval. The log 1/R spectra were transformed into their first and second derivative and Detrend scatter correction (Barnes *et al.*, 1989) was computed at the gaps of 4 nm and smoothing over segments of length of 4 nm. Calibration was performed by using modified partial least square (MPLS) and also modified stepwise (MSR) regression on the range from 1100 to 2498 nm. Cross validation was used to prevent overfitting (Shenk and Westerhaus 1993). All procedures were developed by using ISI software, version 3.10 (Infrasoft International, Port Matilda PA, USA).

Spectral analysis: The following procedure was used to identify the main spectral regions associated with NIRS discrimination for oil. For each calibration set, six samples showing low oil, medium and high values were selected. Three average spectra (low, medium and high oil content) were then created for each calibration set. First [1,4,4,1] and second [2,4,4,2] derivative transformation and scatter correction were applied to the new spectra, as described previously, and standard deviation among average spectra for each new created set were studied to identify spectral changes associated with change in oil content.

Oil content of seeds: Following three methods were used for oil content determination:

Method I (Standard method): Seeds dried at 105°C for 16-18 hours (drymatter basis with moisture level below 3%) were used. The extraction was performed as follows:

An amount of 22g dried seed ground in a hand mill was weighed into two portions of 10g each. The samples were placed in Soxhlet tubes and extracted for 16 hours with petroleum ether (bp 40-60°C). Afterwards, samples were ground in a mortar and again extracted for 16 hours. The petroleum ether was evaporated, and the oil was dried to a constant weight, in an incubator at 100°C; afterwards, the oil percentage was calculated.

Method II: The oil content was determined in the seed without drying otherwise as in method I.

Method III: Oil content was determined on drymatter basis by Nuclear Magnetic Resonance (NMR) spectrometry technique. Newport 4000 analyzer from Oxford Analytical Instruments Limited was used for this purpose.

The instrument was calibrated by taking 20g pure oil and adjusting it to radio frequency 225µA; audio frequency gain 400, integration time 30s and gate width of 1.0 to receive direct oil value of samples as determined by Method I.

Results and discussion

Distribution of total oil content in population of two calibration sets from crop grown during 1998-99 and 2000-01 (*rabi* season), determined at average 8.5% *moisture basis (as received) by Soxhlet extraction method* are shown in figure 1 and figure 2 respectively. Range of oil content was from 32.13-46.83% for samples from 1998-99 crop year (calibration set I). With the introduction of new set of samples, range of oil value increased from 27.42-51.32% (calibration set III).

Average reflectance spectra for the set of similar samples from 1998-99 crop year at their intact and ground forms and for the another set of samples from 2000-01 crop year at their moisture level of 8.5% (as received) and 3% (dried seeds) are shown in figure 3 and figure 4 respectively. Reflectance spectra for whole and ground seed are quite similar, indicating that both spectra probably contain similar compositional information. Some of the peaks in the ground samples are better resolved as is illustrated by the height of 2310 and 2346 nm absorption peaks. Reflectance spectra for the samples having two different levels of moisture are also similar except at 1932 nm absorption peak which is more prominent for higher moisture containing samples.

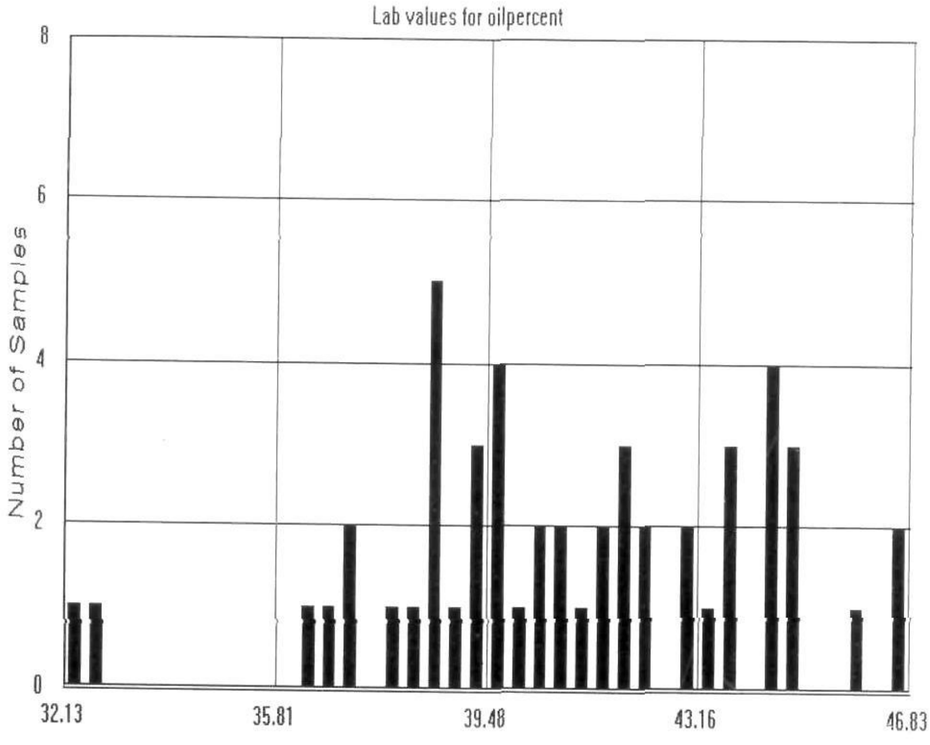

Fig. 1 Distribution of total oil content in the population of crop grown during *rabi*, 1998-99 used for calibration set I and II

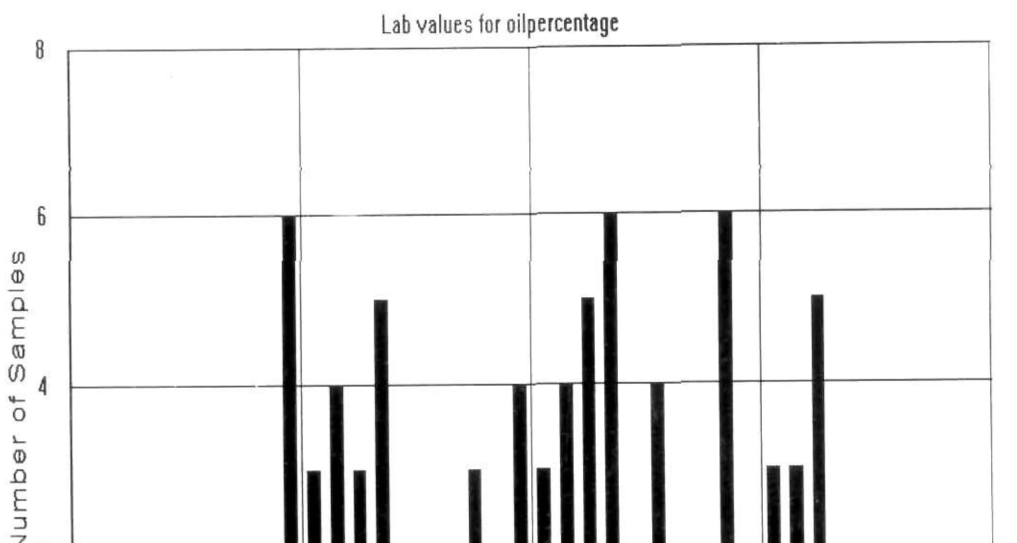

Fig. 2 Distribution of total oil content in the population of crop grown during *rabi*, 2000-01 used for calibration set III

Fig. 3 Average reflectance spectra for whole seed (A) and ground seed (B) in rapeseed-mustard germplasm

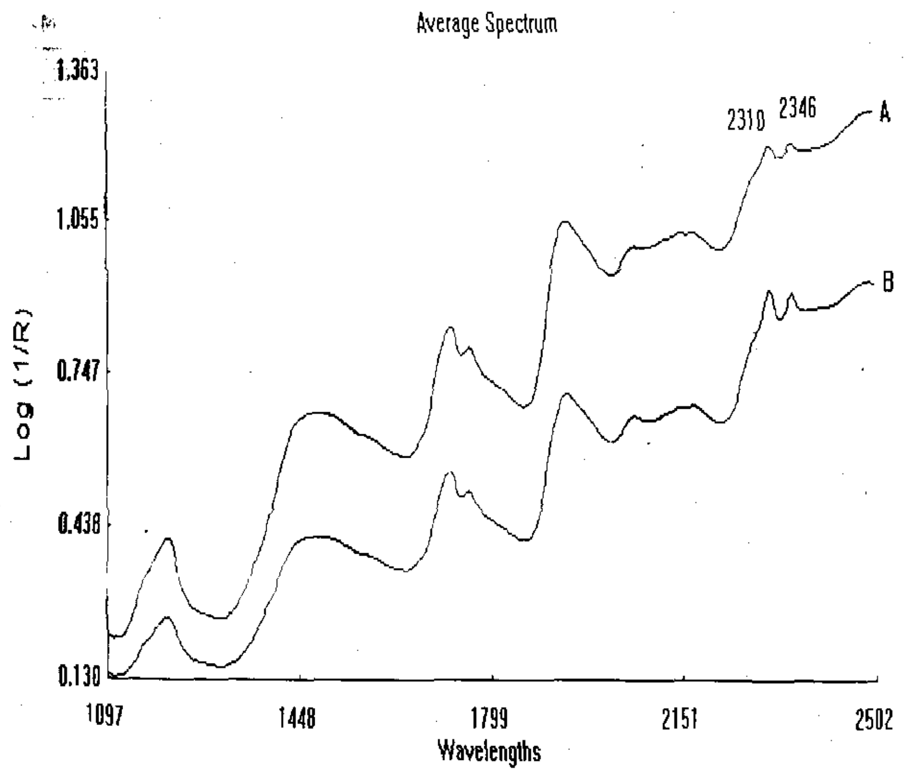

Fig. 4 Average reflectance spectra for whole seed at average 8.5% moisture level (A) and at below 3% moisture level (B)

Table 1 Regression and prediction statistics of NIR equations before elimination of *undesirable* seed samples of rapeseed-mustard

Statistical parameter	Details of samples and NIR regression mode															
	MPLS								MSR							
	Math treatment [1,4,4,1]				Math treatment [2,4,4,1]				Math treatment [1,4,4,1]				Math treatment [2,4,4,1]			
	2001-01 crops		1998-99 crops		2000-01 crops		1998-99 crops		2000-01 crops		1998-99 crops		2000-01 crops		1998-99 crops	
	Intact	Oven dried	Intact	Ground	Intact	Oven dried	Intact	Ground	Intact	Oven dried	Intact	Ground	Intact	Oven dried	Intact	Ground
Range	27.42-51.32	28.88-53.08	32.13-46.83	32.13-46.83	27.42-51.32	28.88-53.08	32.13-46.83	32.13-46.83	27.42-51.32	28.88-53.08	32.13-46.83	32.13-46.83	27.42-51.32	28.88-53.08	32.13-46.83	32.13-46.83
Mean	39.82	41.72	40.92	40.93	39.82	41.72	40.92	40.93	39.82	41.72	40.92	40.93	39.82	41.72	40.92	40.93
SD	5.556	5.768	3.225	3.217	5.556	5.768	3.225	3.217	5.556	5.768	3.225	3.217	5.556	5.768	3.225	3.217
R^2	0.965	0.984	0.962	0.960	0.971	0.985	0.963	0.962	0.971	0.987	0.957	0.955	0.976	0.986	0.963	0.954
SEC	1.037	0.718	0.626	0.646	0.947	0.698	0.622	0.626	0.953	0.652	0.666	0.681	0.859	0.674	0.619	0.688
1-VR	0.957	0.970	0.937	0.919	0.950	0.973	0.929	0.864	0.067	0.986	0.951	0.943	0.973	0.985	0.959	0.937
SECV	1.150	0.995	0.803	0.919	1.242	0.939	0.851	1.189	0.995	0.670	0.707	0.763	0.909	0.706	0.643	0.801

Table 2 Regression and prediction statistics of NIR equations after elimination of undesirable seed samples of rapeseed-mustard

Statistical parameter	Details of samples and NIR regression mode															
	MPLS								MSR							
	Math treatment [1,4,4,1]				Math treatment [2,4,4,1]				Math treatment [1,4,4,1]				*Math treatment [2,4,4,1]*			
	2001-01 crops		1998-99 crops		2000-01 crops		1998-99 crops		2000-01 crops		1998-99 crops		2000-01 crops		1998-99 crops	
	Intact	Oven dried	Intact	Ground	Intact	Oven dried	Intact	Ground	Intact	Oven dried	Intact	Ground	Intact	Oven dried	Intact	*Ground*
Range	27.87-50.15	29.56-53.08	32.13-46.83	32.13-46.83	27.87-50.15	28.88-53.08	32.13-46.83	32.13-46.83	27.87-51.32	28.88-53.08	32.13-46.83	32.13-46.83	27.87-50.15	28.88-53.08	32.13-46.83	32.13-46.83
Mean	39.87	41.75	40.87	40.95	39.95	41.43	40.99	40.86	39.98	41.60	40.91	40.93	39.86	41.62	40.92	40.93
SD	5.305	5.649	3.290	3.276	5.285	5.748	3.045	3.209	5.376	5.851	3.339	3.217	5.270	5.771	3.225	3.217
R^2	0.982	0.991	0.981	0.970	0.982	0.991	0.991	0.920	0.985	0.993	0.983	0.955	0.985	0.990	0.963	0.954
SEC	0.704	0.544	0.452	0.570	0.708	0.556	0.294	0.906	0.669	0.474	0.434	0.681	0.648	0.565	0.619	0.688
1-VR	0.980	0.981	0.975	0.957	0.978	0.984	0.982	0.881	0.983	0.993	0.980	0.943	0.984	0.989	0.959	0.937
SECV	0.756	0.777	0.520	0.680	0.783	0.730	0.412	1.105	0.689	0.492	0.471	0.763	0.673	0.594	0.643	0.801

SD = Standard deviation; R^2 = *Squared co-efficient of multiple* determination in calibration. In cross validation, it is estimated as 1 minus variance ratio (1-VR)
SEC = Standard error of calibration (% oil in seed)
SECV = Standard error of cross validation in modified parental least squares regression (% oil in seed). *Math treatment a, b, c, d*
a = derivative *function*; *b = gap*; c = smooth; d = second smooth; MPLS = Modified partial least square; MSR = Modified stepwise regression

Differences in oil concentration of the samples for all the four calibration sets were found associated with spectral differences, mainly located at the spectral region of 2290-2348 nm and 1690-1764 nm irrespective of mathematical treatment of [1,4,4,1] and [2,4,4,1] used in the present study. The spectral regions of 2290-2336 nm and 1690-1732 nm are responsible for bond vibration of C-H first overtone of CH_2, CH_3 group and C-H combinations of CH_2, CH_3 group respectively. This represents the basis for NIRS discrimination of oil from other constituents of the seeds. Most of them belong to the principal spectral regions associated with fatty acids present in rapeseed-mustard seeds (Barnes *et al.*, 1989; Shenk and Westerhaus, 1993).

With the four calibration sets, equal numbers of 16 best equations were developed. Among these eight equations were developed with MPLS (modified partial least square) mode and remaining eight equations by MSR (modified stepwise regression) mode. Identical math treatment were followed to obtain eight first derivative equations [1,4,4,1] and eight second derivative equations [2,4,4,1]. Similarly corresponding sixteen other equations were also developed by applying the elimination process which involves only the selected samples that give less than 2.5 residual value in regression process (Fig. 5; 6).

Dried samples give better regression statistics in comparison to their counterpart sets at moisture level of 8.5% from 2000-01 crop year. It may be assumed that by Soxhlet extraction method, samples give more accurate oil value if they are taken in dry condition. Squared co-efficient of multiple determination (R^2) and Standard error of calibration (SEC) value in sixteen equations developed with all the samples (Table 1) varied within the range of 0.955-0.987 and 0.619-1.037 respectively. Ratio of SD (standard deviation) and SEC of the equations were within the range of 8.84 to 4.67. Ideally the SD of the calibration set should be at least ten times larger than the SEC to ensure a good calibration (Panford and deMan, 1990). Equations with good regression statistics can be obtained if elimination process is applied to remove the undesirable samples with minimum residual values of 2.5 (Table 2). SD and SEC ratio of all the four calibration equations developed with selected dried samples (calibration set-IV) were within the range of 12.34 to 10.21 in comparison to 10.35 to 3.54 ratio values obtained for the remaining equations. Comparatively better regression statistics were obtained for the equations developed with intact selected samples than their counterpart set of ground samples from 1998-99 crop year. Neither math treatment nor regression mode used in the present study has any appreciable effect on regression statistics of the equations.

Eight equations from each calibration file generated a total of twenty four R^2 (Coefficient of determination in external validation) and SEP (standard error of prediction in external validation) values when they were tested against the three remaining calibration files as external validation. Respective R^2 and SEP values were compared to select the equation having wider prediction capability. Because of obvious reasons R^2 values are given more consideration than SEP values, as calibration files are different in their population structure, physical morphology and for samples being grown in different environments. R^2 values of the tested equations varied within the range of 0.808 to 0.921. The performance of the equations developed with whole seed samples is found better and varied within the impressive range of 0.845 to 0.948 when were tested against the other whole seed based calibration files irrespective of their moisture level and other differences. Equations derived from year 2000-01 crop at 3.0% moisture level (calibration set-IV) comparatively produced low average SEP values followed by Calibration set-I, calibration set-III and calibration set-II.

The best equation from calibration set-IV with SEC value of 0.474 was found to give very good average prediction statistics (r^2 and SEP) in comparison to remaining thirty one equations when tested against other calibration sets. These best equation along with other equations were again tested with a new validation set (calibration set-V) consisting of 259 new rapeseed-mustard samples of *B.napus*, *B.juncea* and *B.rapa* grown during Rabi 2002-03 with oil content range of 30.87 to 49.66%. The best prediction plot and prediction statistics performed by the same equation is shown in Figure. 7.

In general, first derivative equations developed with selected samples from the respective calibration file by stepwise mode of regression are better performing and give comparatively low average SEP. On the other hand, it is only two second derivative equations among other six equations from calibration file containing ground samples and developed by MPLS mode of regression that produce comparatively low average SEP value when tested against other three calibration sets containing intact seeds.

All the MPLS based second derivative equations developed with total samples always performed as the second best for predicting oil values of the samples irrespective of their physical morphology, growing year and moisture level.

Conclusion: Regression and prediction statistics of the thirty two calibration equations developed with four calibration sets, were compared to select the best equation for its wider capability to measure oil content of the rapeseed-mustard seeds.

The first derivative equation [1,4,4,1] developed with selected dried samples from 2000-01 crop by modified stepwise regression was found to give impressive regression values of 0.993 and 0.474 for R^2 and SEC statistics respectively.

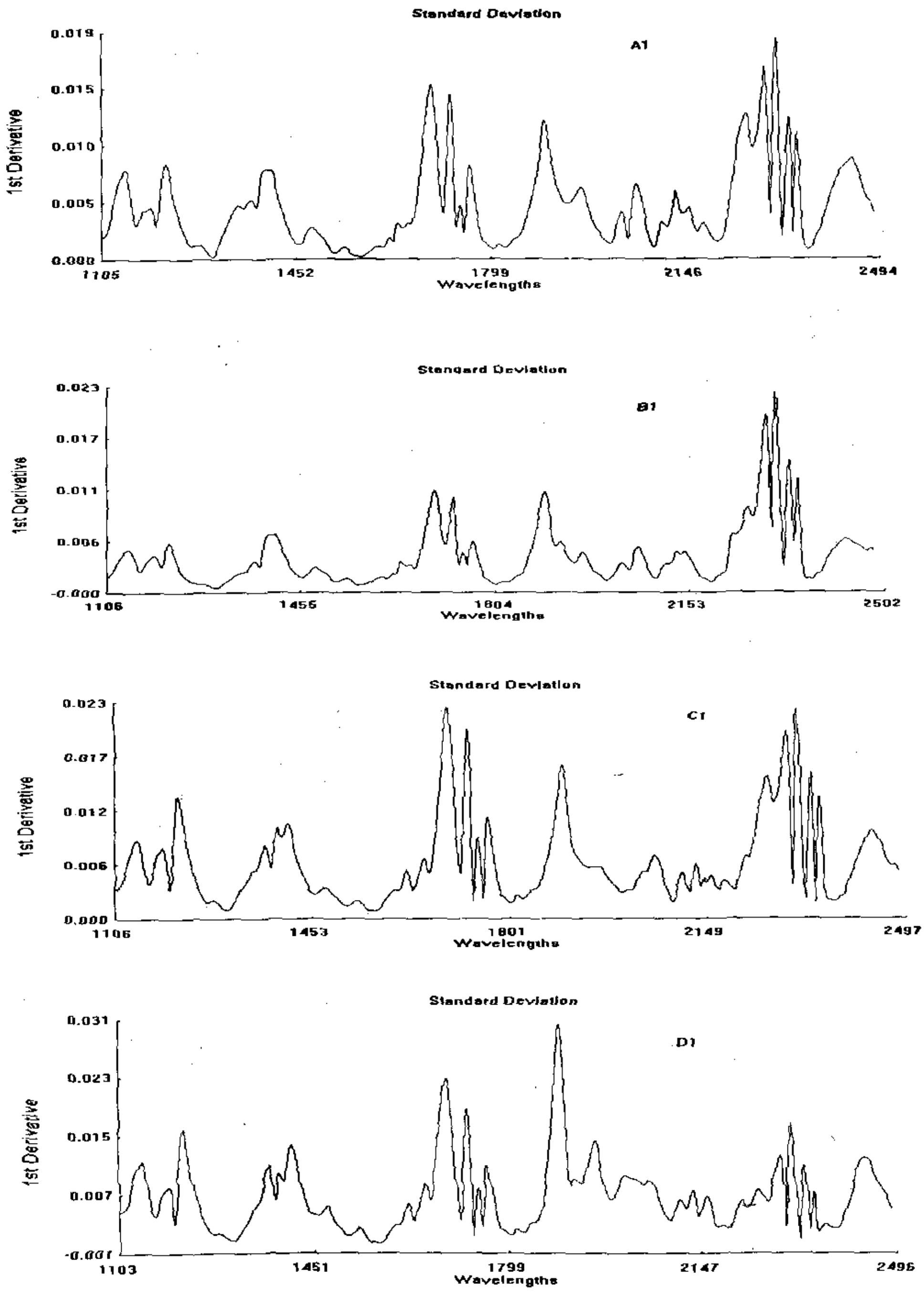

Fig. 5 Standard deviation (std. dev.) among first derivative average spectra (low, medium, high oil content). A1, Intact seed from crop year 1998-99; B1, Ground seed from crop year 1998-99; C1, Intact seed at 8.5% moisture level from crop year 2000-01; D1, Intact seed at 3% moisture level from crop year 2000-01

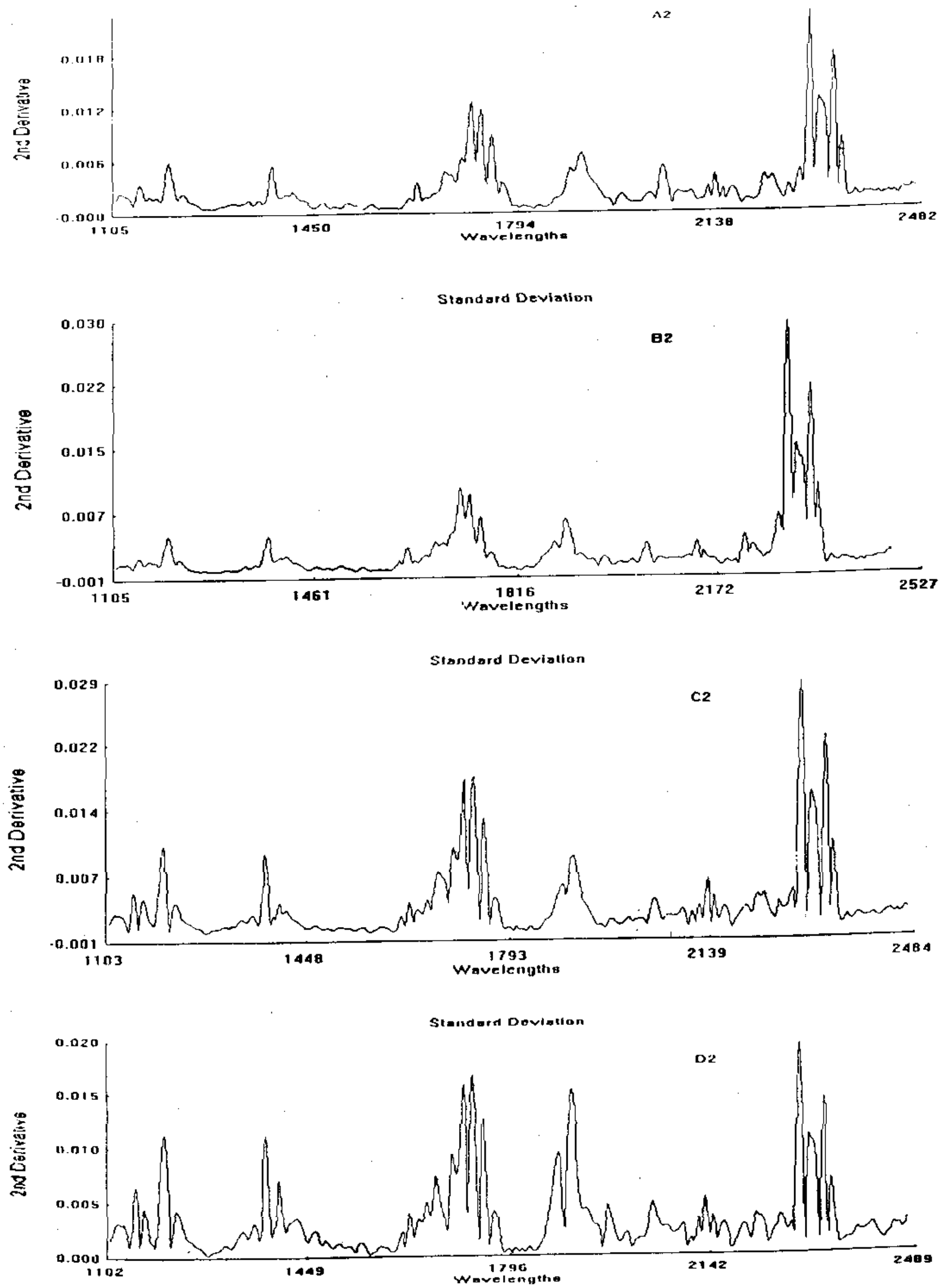

Fig. 6 Standard deviation (std. dev.) among second derivative average spectra (low, medium, high oil content). A2, Intact seed from crop year 1998-99; B2, Ground seed from crop year 1998-99; C2, Intact seed at 8.5% moisture level from crop year 2000-01; D2, Intact seed at 3% moisture level from crop year 2000-01

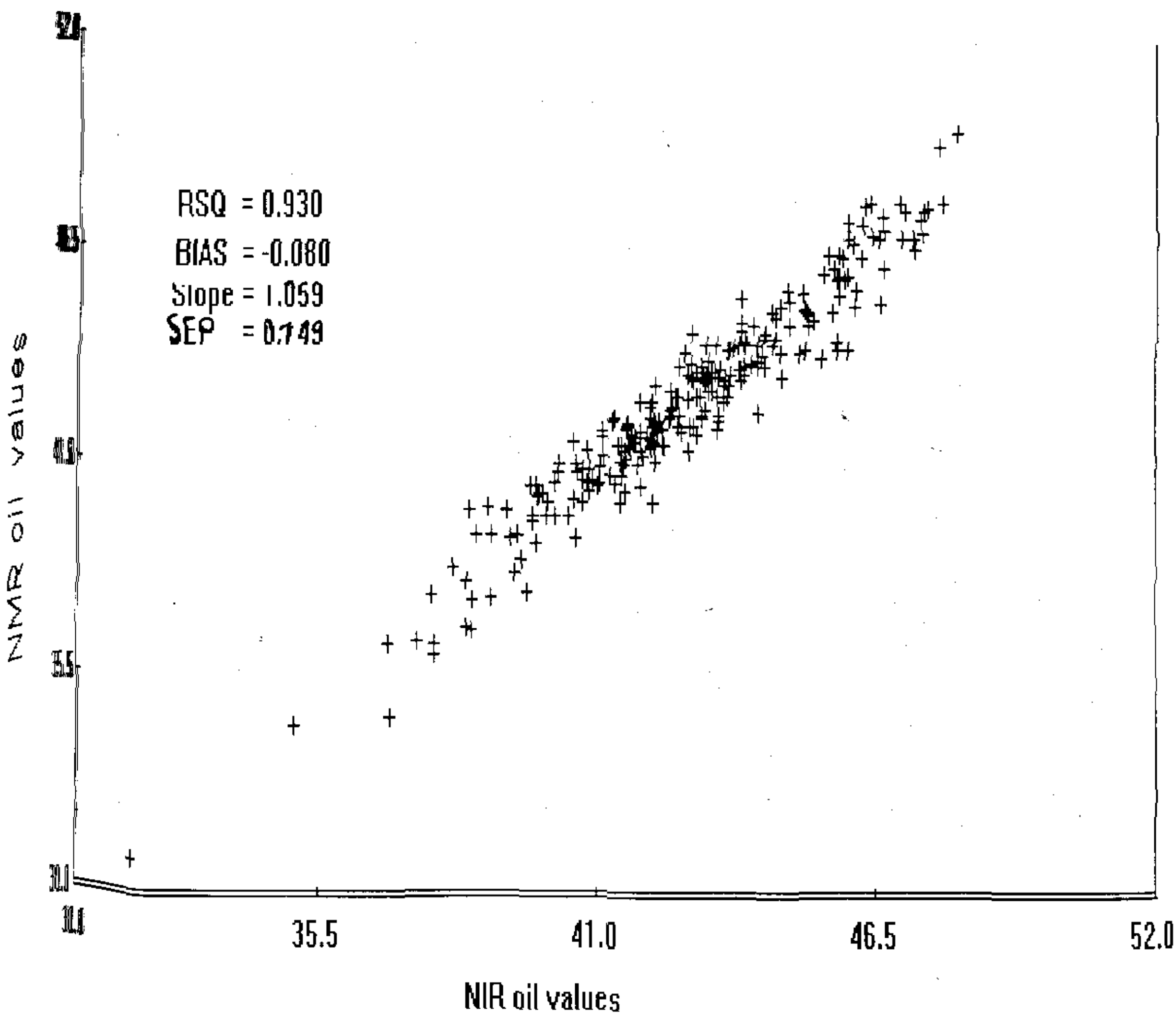

Fig 7 Prediction plot for total oil content (g seed oil/100 g seed), NIRS data vs. NMR data for 259 samples of the validation set (calibration set-V)

The average R^2 and SEP value of this equation for the prediction tests against the three validation sets (calibration set-I, II and III) was found 0.913 and 1.490 respectively.

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Effect of integrated nutrient management on matter production, water use efficiency and productivity of soybean, *Glycine max* (L.) Merill in vertisols of central India

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Abstract

A field experiment was conducted for two years (2000-2001) during rainy season on deep vertisols of Bhopal, India to study the effect of different nutrient combinations *viz.*, 0,75, 100% recommended dose of nitrogen, phosphorus and potassium (NPK), 75% NPK + farmyard manure (FYM) @ 5t /ha, 75% NPK + poultry manure (PM) @ 1.5 t/ha and 75% NPK + phosphocompost (PC) @ 5 t/ha on dry matter production, water use efficiency and productivity of soybean. The results showed that with the increase in NPK dose from 0 to 100% there was significant improvement in both below (root) and above ground (shoot) dry matter at all the stages of crop growth. Integrated use of organics and inorganics not only recorded significantly more root and shoot dry matter but also accelerated the rate of root and shoot growth compared to only inorganic fertilization. Effect of integrated use of FYM with 75% NPK in terms of dry matter production, water use efficiency and yields of soybean was more prominent than integration with PM and PC. The performance of nutrient combinations followed the order of: 75% NPK + FYM > 75% NPK + PM > 75% NPK + PC > 100% NPK. Thus, the combined use of manures and inorganic fertilizer played a significant role in increasing the above and below ground dry matter, water use efficiency, pod number and its weight resulting in higher seed and oil yield of soybean.

Key words: Integrated nutrient management, vertisols, soybean, phosphocompost

Introduction

Soybean [*Glycine max* (L.) Merrill] is the most important *kharif* oilseed crop grown on vertisols of semi-arid tropics of central India. Though the area under soybean has increased 8 fold during 1982-1996, its productivity gap between achievable potential grain yield of 3 t/ha and current yield level of less than 1.0 t/ha remains very wide (Gupta and Rajput, 2001). Low productivity of the crop is primarily because of uncontrollable climatic factors like erratic rainfall distribution pattern and controllable edaphic factor of low organic matter status owing to imbalanced application of macro-and micro-nutrients through high analysis inorganic fertilizers in a continuous cropping. Soybean utilizes high quantities of nutrients from soil and if not fertilized properly, it causes mining of soil nutrients. Therefore, it is necessary to maintain soil fertility for sustainable production of soybean through judicious use of fertilizers (Bobde *et al.*, 1998). It has been realized from long- term fertilizer experiments that neither chemical fertilizer nor the organics alone can achieve sustainability in production (Prasad 1996; Singh and Dwivedi, 1996). This calls for integrated use of organics and inorganics for highly intensive production system to maintain soil health and to augment the efficiency of nutrients. The declined availability of FYM is being experienced in Madhya Pradesh consequent upon tendency of limiting farm animals due to increasing farm mechanization. Moreover, the commonly adopted practice of burning wheat residue has led to the decline in soil organic matter, pollution of the environment and lowering biological activity. The promotion of turning wheat residues into phosphocompost (PC) during the time-lag of about two and half months (April-June) between the harvest of wheat and planting of *kharif* soybean and its utilisation as alternate to FYM is a feasible option. In addition, the fast developing poultry farming in this region has been able to provide with increased quantities of poultry manure (PM), which contains high concentration of nutrients, can form an integral part in integrated plant nutrient supply system and can meet out shortage of FYM to some extent. Hence, the present investigation was undertaken to study the effects of judicious and combined use of inorganics (NPK) and above three organic manures on growth, water use efficiency and yield of soybean.

Materials and methods

The filed experiment was conducted during rainy (*kharif*) seasons of 2000 and 2001 at the research farm of Indian Institute of Soil Science, Bhopal on deep Vertisols. The soil of the experimental site (*Typic Haplustert*) was clayey having pH 7.8, organic carbon 0.52% and EC 0.52 ds/m. The available soil N, P and L contents were 145, 10.7 and 325 kg/ha, respectively. The saturation water holding capacity, bulk density and porosity of the surface (0-15 cm) soil were 62%, 1.45 Mg/m^3 and 45%, respectively. The experiment was laid out in a Randomized Block Design (RBD) with six nutrients, no fertilizer and manure (F_1), 75% NPK through fertilizers (F_2), 100% of NPK through fertilizers (F_3), 75% NPK through fertilizers + 25% through FYM (F_4), 75% of NPK through fertilizer + 25% through phosphocompost (F_5) and 75% of NPK through fertilizer + 25% through PM (F_6) with four replications. The dose of organic manure was fixed based on N equivalence (0.73, 0.80 and 2.14% N in FYM, PC and PM, respectively) and their quantities required to substitute 25% N were 5, 5 and 1.5 t/ha, respectively. The recommended dose of N : P_2O_5: K_2O (100% RDF) used for soybean were 30 : 60 : 30 kg/ha. Entire dose of nitrogen, phosphorus and potassium were applied at sowing through urea, single superphosphate and muriate of potash, respectively. Phosphocompost was prepared using fresh cowdung, soil and wheat straw in the ratio of 1:0.5:1 (dry weight basis). Pyrite (S-22.2%) @10%, 2.2% P through mussoorie rock phosphate (100 mesh) and N @ 0.5% through urea were added to the mixture on dry weight basis. The materials were allowed to decompose for a period of 90 days.

Soybean (JS 335) at 30 cm x 10 cm spacing was sown in first week of July during *kharif* and harvested at 95 days in first year and at 91days at second year. The total rainfall received during the first and second year (June - October) was 693.3 and 766.6 mm, respectively. However, there was less rain during grain filling stage in second year than first year. Plant samples were collected from 0.5 m^2 land area at different stages crop growth and oven-dried at 65°C till constant weight. Dry matter was determined based on the fresh weight of sample plants and the moisture content of the sub samples. Water-use efficiency was calculated by dividing seed yield with the respective value of seasonal evapo-transpiration of the crop calculated by water balance method

Statistical analysis of data was carried out using standard analysis of variance (Gomez and Gomez, 1984). The significance of the treatment effect was determined using the F-test and to determine the significance of the difference between the means of the two treatments, least significances (LSD) were estimated at the 5% probability level.

Results and discussion

Dry matter production: Data pooled over two years showed that with the increase in NPK dose from 0 to 100% there was significant increase in both below (root) and above ground (shoot) dry matter (DM) at all the stages of crop growth. The beneficial effect of applied NPK on DM and productivity of soybean was attributed to increased crop growth and relative growth rate (Hasnabade *et al.*, 1990). However, integrated use of organics and inorganics recorded significantly more DM compared to inorganics at all the stages (Table 1). Shoot and root growth with the combined use of organics and inorganic were faster than only inorganic fertilizer application. The shoot growth rate was 11.9, 11.9,9.9 g/m^2/d between 30-60 DAS and 4.2, 4.9, 6.0 g/m^2/d between 60 DAS and harvest with NPK+FYM, NPK+PC and NPK+PM, respectively *vis-a-vis* 8.6 and 3.9 g/m^2/d with 100% NPK. Similarly, root growth rate was 0.9, 0.8, 0.9 g/m^2/d between 30-60 DAS and 0.3,0.2,0.3 g/m^2/d between 60 DAS and harvest with NPK+FYM, NPK+PC and NPK+PM, respectively vis-a-vis 0.6 and 0.1 g/m^2/d with 100% NPK. Application of 75% NPK in combination with FYM @ 5 t/ha recorded significantly higher above ground DM at 30 and 60 DAS over other nutrient treatments but at harvest effects of all three organic sources on above ground DM were statistically at par. Except at 30 DAS, effects of all three organic sources on below ground DM were at par but these were significantly higher over inorganics (Table 1).

Water use efficiency: The effect of inorganic fertilizer application on water use efficiency (WUE) was not significant. Though effect of all three organically treated plots on WUE was at par, the integrated use of FYM and NPK fertilized plots registered significantly higher water use efficiency than the plots receiving either inorganic fertilizer alone or no fertilizer. The increase in WUE with the combined application of fertilizer and manure might be due to more rapid root and shoot growth (Table 1) during crop growing periods with lower vapour pressure deficit which decreased evaporation : transpiration (Es/T) ratio and improved transpiration efficiency (Zhang *et al.*, 1998).

Yield and yield attributes: In general, number of pods, pod weight, 1000-seed weight, seed and stover yield of soybean were higher in first year than second year because of early withdrawal of monsoon during the grain filling stage of soybean in the second year. Effect of inorganic NPK-fertilizer was not significant on seed yield of soybean but significant on all the yield attributes and stover yield of soybean when compared with control. Pod number and pod weight of soybean increased at 75% NPK level which remained at par with 100% NPK. The stover yield increased numerically with increasing levels of NPK during both the years; however significant difference was observed at 100% NPK level over control (Table 2).

Table 1 Effect of nutrient management on dry matter and water use efficiency of soybean (pooled over two years)

Treatment	Above ground dry matter (g/m^2)			Below ground dry matter (g/m^2)			Water use efficiency (kg/ha-cm)
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	
Control	24.9	154.8	288.6	4.8	18.6	19.2	18.5
75% recommended NPK	32.1	268.4	384.6	5.1	21.4	22.5	20.9
100% recommended NPK	39.4	296.2	432.2	5.9	24.8	26.4	21.3
75% recommended NPK + FYM @ 5 t/ha	63.0	420.6	567.6	9.6	36.0	45.7	24.3
75% recommended NPK + PC @ 5 t/ha	34.8	390.3	561.3	6.0	31.2	38.1	22.8
75% recommended NPK + PM @ 1.5 t/ha	33.6	329.2	538.0	6.9	36.6	43.5	23.7
CD (P=0.05)	2.8	11.2	85.7	0.8	4.2	5.9	2.9

FYM = Farmyard manure; PC = Phosphocompost; PM = Poultry manure

Table 2 Effect of nutrient management on yield attributes and yield of soybean

Treatment	Pods/plant (No.)		Pod weight/plant (g)		1000-seed weight (g)		Seed yield (kg/ha)		Stover yield (kg/ha)		Oil yield (kg/ha)	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Control	18	16	6.6	5.5	72.2	64.3	955	983	1619	1932	163	175
75% recommended NPK	26	25	7.5	7.9	75.1	69.3	1154	1129	1762	2177	200	207
100% recommended NPK	26	25	9.2	8.9	82.1	74.8	1256	1200	2160	2391	222	224
75% recommended NPK + FYM @ 5 t/ha	45	39	13.5	12.5	102.1	93.8	1715	1441	2784	2871	307	280
75% recommended NPK + PC @ 5 t/ha	37	38	12.3	12.3	80.8	91.5	1272	1311	2350	2679	223	254
75% recommended NPK + PM @ 1.5 t/ha	41	38	12.5	12.1	91.3	89.7	1426	1361	2581	2586	252	261
CD (P=0.05)	5.3	3.8	1.9	1.3	7.6	6.8	367	348	494	386	17.6	14.8

FYM = Farmyard manure; PC = Phosphocompost; PM = Poultry manure

Integrated use of organics and inorganics recorded higher pod number, pod weight, 1000-seed weight, seed and stover yield of soybean compared to inorganics. Beneficial effect of combined use of organics and inorganics in boosting up crop yields as well as maintaining soil health on long-term basis has been reported by Mishra *et al.* (1990). Role of organics in increasing yield of soybean is attributed to supply of all essential nutrients due to continuous mineralization of organic manures. Among various nutrient combinations, integrated use of 75% NPK and FYM @ 5t /ha recorded the highest seed and stover yield of soybean in both years. An increasing trend in oil yield was recorded with levels of inorganic fertilization over control. Like seed yield of soybean, integrated use of organics and inorganics recorded higher oil yield as compared to inorganics fertilization. Application of 75%

NPK and FYM @ 5 t/ha recorded significantly higher oil yield over rest of the treatments during both the years. Higher oil yield with the application of organics is associated with higher seed yield and improvement in oil content. It is noteworthy that the performance of nutrient treatments in terms of seed, stover and oil yields followed the same order i.e. 75% NPK + FYM > 75% NPK+PM > 75% NPK +PC> 100% NPK. The response of soybean to FYM application may be attributed to better nutrient availability enhanced inherent nutrient supplying capacity of the soil and its favourable effect of soil physical and biological properties (Hati *et al.*, 2001). According to Edward and Daniel (1992) if poultry manure is added in combination with chemical fertilizer, it supplements all nutritions to crop, thereby, boost up the productivity of crop. Effect of PC on DM, yield attributes and yield of soybean was not as prominent as FYM and PM. However, yield obtained with 75% NPK and PC @ 5 t/ha was comparable to 100% NPK. Manna *et al.* (1999) also reported that phosphocompost @ 5 t/ha yielded soybean almost on par with NPK applied at full recommended dose. Higher yields of soybean obtained in the combined use of manured and fertilized plots in the present study are attributed to higher and rapid shoot and root growth and improved water use efficiency. Higher yields of soybean in the combined use of manure and fertilizer plots were also evident from improved pod number, pod weight and 1000-seed weight. Over all, the combined use of manures and inorganic fertilizer played a significant role in increasing the above and below ground dry matter, water use efficiency, pod number and its weight resulting in higher seed and oil yield of soybean.

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Sulphur requirement and its use efficiency by soybean, *Glycine max* (L.) Merrill with different sources on an Alfisol

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Abstract

An investigation was carried out to find the requirement of S and its use efficiency by soybean when supplied through different sources on a S-deficient Alfisol. It was found that a minimum of 30 kg S/ha is needed to obtain good yields of soybean although higher levels of its application had beneficial effect on the crop, albeit, to an extent of 3-4 % for each increment of S. Crop foliage was found to be one of the main contributor for the turn over of not only the soil-S but also applied nutrient S as it recorded highest fertilizer S uptake (0.80 kg/ha) after seed (1.18 kg/ha). The other parts such as stems, pod shell recorded only half of such uptake, individually (0.40 kg each/ha). The mean applied S use efficiency determined through employment of S-35 was found to be to an extent of about 8% only by the crop. The mean S-use efficiency by the crop doubled from 3.41% at flowering stage to 7.37 by harvest coupled with similar trend in S-uptake indicating that there is a need to provide good supply of this nutrient to soybean in between flowering and harvest stages. Among the two sources used for S supply, gypsum was found to help in higher use efficiency per unit amount of nutrient applied (7.68%) when compared to that of potassium sulphate. However, the sources did not influence the amount of S required for the crop.

Key words: Soybean, sulphur, per cent Sdff, utilisation, Alfisol

Introduction

Soybean, hitherto in the process of becoming popular in black soils of different parts of Andhra Pradesh is also been the attention of farmers in the Alfisol occurring areas in the state. It is mainly because of its well-known adaptability, remuneration and particularly so for the purpose of providing fresh seed to the subsequent season. Raising of soybean for the purpose of seed often cuts across the recommended dates of sowing, fertilizer application, etc., due to increased recovery of cost compensating the reduced yields. Thus, a late *rabi* or summer sown crop will be very much useful to provide fresh seed to the ensuing season as long as necessary precaution and plant protection measures are adopted to ensure the prevention of occurrence of rust to this crop both during the growth season and in the subsequent *kharif*. Sulphur requirement to crops in alluvial soils where S deficiency is well documented was worked out (Aulakh *et al.*, 1990; Khajanchilal *et al.*, 1996) but such generation of information in Alfisols is gaining momentum in view of increasing reports of sulphur deficiency on such soils (Venkata Reddy *et al.*, 2004). Soybean, a crop rich in protein and oil, also needs considerable amount of sulphur and therefore, its requirement on sulphur deficient soils, particularly in Alfisols, needs to be established. Since sulphur is being supplied through different sources, identification of a better one among the available is also an important factor. Hence, the present investigation is contemplated to study the effect of S when supplied through different sources on its requirement and use efficiency by soybean using S-35 radioisotope.

Materials and methods

A field experiment was conducted during summer at Agricultural College Farm of ANGRAU, Rajendranagar, Hyderabad on an Alfisols. The soil of the experimental plot was sandy loam in texture, having the following characteristics which were determined following standard procedures (Tandon, 1993) - pH 7.56; EC 0.40 dS/m; available N 125, P_2O_5 24, K_2O 414 kg/ha; free $CaCO_3$ 1.5% and $CaCl_2$ extractable available sulphur 8 mg/kg. The experiment was laid out during first fortnight of February in Split Plot Design with two main treatments (gypsum and potassium sulphate as sources of S) and six sub-treatments (0.15, 30, 45, 60 and 75 kg S/ha as levels of S) replicated thrice. The sulphur in the gypsum and potassium sulphate was tagged with S-35 radioisotope to a final specific activity of 9.25 M q (0.25 mCi)/g of S. The tagged S was applied to microplots within the corresponding main plots which were treated with non-tagged sulphur. A uniform dose of 60 kg N and 80 kg P_2O_5/ha was supplied through DAP and urea, respectively. Other standard package of practices of cultivation of the crop were followed during experimentation. The crop

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samples collected both at flowering and harvesting stages were analysed for sulphur and radioassay (IAEA, 1990) separately in leaves, stems, pod shells and seeds as the case may be. The radiation counting was done with a Geiger-Muller Counter (Model-RCS 4207 A).

Results and discussion

Drymatter production and seed yield: Different levels of sulphur application have significantly influenced the total drymatter and seed yield both at flowering stage and by harvest, respectively (Table 1). Even the weightage of different parts of the plant such as leaves and stems at flowering stage and pod shells and seed at harvest were individually affected by graded application of sulphur. The total drymatter yield of the crop at flowering stage was highest when S was applied at 75 kg/ha but it was on par with the application of 60, 45 and 30 kg S/ha. At the same time, application of 15 kg S/ha to soybean was found to record on par drymatter yield to that of 30 kg/ha. The individual parts of stem and leaves at flowering stage of the crop were also found to register higher yields with the increasing levels of S application. Among the levels of S tested, the leaf drymatter was found to be on par between 15 and 30; 30 and 45; 45 and 60 and 60 and 75 kg S/ha. Such a trend of stem biomass due to application of successive higher levels of S application was also observed. The results point out that there is a sharp response by the crop to S application at initial lower levels followed by gradual increase of yield with each increment in the application.

At harvest, the total drymatter yield of soybean increased significantly over that of control. It was highest at 75 kg S/ha and was on par with 60 and 45 kg S/ha. Individual plant parts like leaf drymatter, stem biomass and pod shell production were also influenced by the application of sulphur positively with a general trend of increase in weight with the increments of sulphur application. However, the differences in yield of different individual plant parts between any two consecutive increments of S application were, in general, was found to be non-significant. Such a trend is expected for a crop like soybean that sheds a lot of foliage during crop season and thus, posing a practical problem of accounting the weight of different plant parts. The seed yield of the crop was found to be highest due to application of S at 60 kg/ha (1240 kg/ha) which was on par with that of 75 kg S/ha. It is also evident that the incremental application of S increased the seed yield gradually but such increase was found to be significant only when a minimum dose of 30 kg S/ha was applied when compared to lower levels of application. The response of the crop to S application either in terms of biomass enhancement or seed production is expected in this S deficient Alfisol. However, the maximum increase in seed yield was only to an extent of 20% when 60 kg S/ha was applied to the crop. The increase in seed yield when 30 kg S was applied to the crop was only about 12% when compared to that of control and subsequent increments resulted in the enhancement of the yield only to an extent of 3-4%. These results point out that there is a need to exercise a caution while applying the S beyond 30 kg/ha to this crop which continues to exert positive effect, albeit, to a lesser extent at higher levels.

Application of S to this crop either through gypsum or by potassium sulphate was not found to influence the drymatter production of the crop both at flowering stage and at harvest or the seed yield (Table 1).

Sulphur uptake: The S uptake by the crop increased with the increasing levels of S application due to higher biomass and seed yield. The sources of S, once again, did not influence the S uptake by the crop (Table 2).

Per cent Sdff: Increasing levels of S application significantly increased the per cent Sdff in all plant parts at all stages of study. It can be seen from the data (Table 3) that the per cent Sdff was highest in pod shells followed by stems and leaves but at the same time the total S removal (Table 2) by these parts was reverse in the order and hence is evident that the leaves of soybean helps in turnover of applied S to a large extent within the field. This observation was also further confirmed from the data presented in table 4 where the mean fertilizer S uptake by it was the highest (0.8 kg/ha) increase in per cent Sdff in the plant parts of the crop with the increased fertilizer application is expected as large amounts of S becomes accessible to the crop with the increased application of the nutrient. Similar results of increased per cent nutrient derived from applied fertilizer with the increased application of the nutrient was reported in several crops (Khajanchilal *et al.*, 1996; Venkat Reddy *et al.*, 2004). The mean per cent Sdff in seeds of the crop was found to be significantly higher when the S was applied through the gypsum when compared with that of potassium sulphate. The S in gypsum being available slowly due to lower solubility of gypsum would have helped in steady availability of S to the crop and thus would have helped in higher per cent Sdff in the seeds of the crop by the time crop reached to maturity.

Fertilizer S uptake: It is obvious that the total fertilizer S uptake by the crop at maturity was significantly higher when gypsum was used as a source of sulphur. The total fertilizer S uptake by the crop at flowering stage and by the maturity stage increased significantly with each increment in S application and reached to the highest when S @ 75 kg/ha was applied (Table 4).

S utilisation and soil S-uptake: The utilization of S by the crop was not influenced by the sources through which it was applied by the time the crop reached the flowering stage. But, by maturity stage, the applied S utilization was found to be highest when gypsum was used as a source compared to that of potassium sulphate. Application of increasing levels of S, on the other hand, significantly decreased S utilization. The sulphur utilization doubled by maturity stage to 7.37 when compared to 3.41 % at flowering stage (Table 5). This observation points out that a lot of S requirement may have to be met from flowering stage onwards to this crop. Thus, special effort can also be made to find out whether S application to this crop can be made just before flowering stage like in case of groundnut. The utilization of sulphur is only to an extent of 7.37% by the crop inspite of deficiency status of the soil.

Table 1 **Effect of sources and levels of sulphur on drymatter production of different parts at flowering and maturity stages of soybean**

Treatment	Drymatter yield (kg/ha)							
	Flowering stage			Maturity stage				
	Leaves	Stems	Total	Leaves	Stems	Pod shells	Seed	Total
Levels of sulphur								
No sulphur	806.0	626.4	1430.9	904.3	684.6	614.2	1034.1	3237.1
15 kg/ha	843.0	670.7	1514.0	946.3	738.2	630.2	1068.9	3383.7
30 kg/ha	862.0	680.6	1543.4	957.1	761.4	661.7	1159.5	3539.8
45 kg/ha	878.0	688.6	1566.6	962.1	769.9	679.3	1197.3	3616.9
60 kg/ha	889.9	691.0	1580.9	961.1	814.8	691.4	1240.3	3676.4
75 kg/ha	884.9	692.3	1583.1	967.4	781.8	693.1	1240.2	3682.5
Mean	860.8	674.9	1535.7	948.7	748.5	661.7	1156.7	3522.5
SEm±	12.2	9.1	20.4	13.0	23.3	11.9	18.5	46.9
CD (P=0.05)	25.4	18.9	42.6	27.1	48.7	24.8	38.6	97.5
Interactions (SxL)	NS	NS	NS	NS	NS	NS	NS	NS
Sources of S								
Gypsum	868.2	674.4	1544.2	952.6	768.6	665.0	1161.4	3542.0
Potassium sulphate	853.2	675.5	1528.8	946.8	748.3	658.3	1152.1	3502.9
SEm±	6.7	7.2	12.2	3.1	9.1	6.3	14.8	26.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 2 **Effect of sources and levels of sulphur on sulphur uptake by different parts of soybean at different stages**

Treatment	Sulphur uptake (kg/ha)							
	Flowering stage			Maturity stage				
	Leaves	Stems	Total	Leaves	Stems	Pod shells	Seed	Total
Levels of sulphur								
No sulphur	1.56	0.47	2.03	1.01	0.51	0.62	2.39	4.53
15 kg/ha	2.18	0.83	3.01	1.75	0.73	0.69	3.29	6.46
30 kg/ha	2.64	1.05	3.69	2.05	0.84	0.77	3.79	7.45
45 kg/ha	2.95	1.17	4.12	2.19	0.90	0.87	3.99	7.95
60 kg/ha	3.36	1.28	4.64	2.37	0.94	0.88	4.33	8.52
75 kg/ha	3.35	1.33	4.68	2.40	0.92	0.90	4.28	8.51
Mean	2.67	1.02	3.69	1.96	0.81	0.79	3.68	7.20
SEm±	0.078	0.043	0.102	0.067	0.018	0.020	0.119	0.207
CD (P=0.05)	0.16	0.09	0.21	0.14	0.04	0.04	0.25	0.43
Interactions (SxL)	NS	NS	NS	NS	Sig.	NS	NS	NS
Sources of S								
Gypsum	2.66	1.01	3.67	2.06	0.82	0.79	3.66	7.25
Potassium sulphate	2.69	1.03	3.72	1.87	0.80	0.79	3.70	7.15
SEm±	0.125	0.016	0.136	0.032	0.006	0.011	0.115	0.128
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 3 Effect of sources and levels of sulphur on per cent Sdff in different parts of soybean at different stages

Treatment	% Sdff					
	Flowering stage			Maturity stage		
	Leaves	Stems	Leaves	Stems	Pod shells	Seeds
Levels of sulphur						
15 kg/ha	23.70	31.00	30.60	33.52	38.78	24.72
30 kg/ha	27.75	33.10	35.25	40.53	43.20	26.00
45 kg/ha	29.68	41.10	37.83	44.70	46.95	29.23
60 kg/ha	33.40	45.02	38.90	49.35	52.72	32.75
75 kg/ha	37.67	50.18	41.17	58.67	58.18	37.80
Mean	30.44	40.08	36.75	45.32	47.97	30.10
SEm±	1.078	1.535	0.973	1.040	1.210	1.066
CD (P=0.05)	2.29	3.25	2.06	2.21	2.57	2.26
Interactions (SxL)	NS	NS	NS	Sig.	NS	Sig.
Sources of S						
Gypsum	28.98	42.79	37.53	48.72	47.40	31.26
Potassium sulphate	31.90	37.37	35.97	41.91	48.53	28.94
SEm±	0.760	0.387	0.185	0.428	0.724	0.256
CD (P=0.05)	NS	1.67	0.016	1.84	NS	1.10

Table 4 Effect of sources and levels of sulphur on fertilizer sulphur uptake by different parts of soybean at flowering and maturity stages

Treatment	Fertilizer S uptake (kg/ha)							
	Flowering stage			Maturity stage				
	Leaves	Stems	Total	Leaves	Stems	Pod shells	Seed	Total
Levels of sulphur								
15 kg/ha	0.51	0.24	0.75	0.54	0.25	0.27	0.72	1.78
30 kg/ha	0.72	0.36	1.08	0.72	0.34	0.34	0.97	2.37
45 kg/ha	0.88	0.48	1.36	0.83	0.40	0.41	1.16	2.80
60 kg/ha	1.12	0.58	1.70	0.92	0.46	0.47	1.42	3.27
75 kg/ha	1.26	0.67	1.93	0.99	0.54	0.52	1.62	3.67
Mean	0.90	0.47	1.37	0.80	0.40	0.40	1.18	2.78
SEm±	0.037	0.026	0.050	0.026	0.013	0.013	0.058	0.058
CD (P=0.05)	0.08	0.06	0.11	0.06	0.03	0.03	0.12	0.12
Interactions (SxL)	NS	NS	NS	NS	Sig.	NS	NS	NS
Sources of S								
Gypsum	0.85	0.50	1.35	0.86	0.44	0.40	1.21	2.91
Potassium sulphate	0.94	0.44	1.38	0.74	0.36	0.40	1.15	2.65
SEm±	0.018	0.020	0.03	0.011	0.013	0.04	0.067	0.04
CD (P=0.05)	0.08	NS	NS	0.05	0.06	NS	NS	0.17

Table 5 Effect of sources and levels of sulphur on sulphur utilization (%) and soil S uptake (kg/ha) by soybean

Treatment	Sulphur utilization (%)		Soil S uptake (kg/ha)	
	Flowering stage	Maturity stage	Flowering stage	Maturity stage
Levels of sulphur				
15 kg/ha	5.04	12.35	2.26	4.60
30 kg/ha	3.58	7.90	2.29	5.03
45 kg/ha	3.02	6.23	2.77	5.17
60 kg/ha	2.82	5.46	2.91	5.25
75 kg/ha	2.57	4.89	2.78	4.85
Mean	3.41	7.37	2.45	4.89
SEm±	0.14	0.186	0.15	0.14
CD (P=0.05)	0.29	0.39	0.29	0.28
Interactions (SxL)	NS	NS	NS	NS
Sources of S				
Gypsum	3.30	7.68	2.42	4.86
Potassium sulphate	3.51	7.05	2.47	4.92
SEm±	0.14	0.10	0.07	0.10
CD (P=0.05)	NS	0.05	NS	NS

The soil S uptake by the crop at flowering and maturity stages by different plant parts was not found to be influenced by either different levels of S or its sources (Table 5). One possible reason for such observation could be that the soil under investigation has a considerable reserve of total S (163 kg/ha) which can mask subtle differences of soil S uptake by the crop when applied S used efficiency is also to a small extent of about 8%.

Thus, the present study indicated that a minimum of 30 kg S/ha would be beneficial to soybean crop in S-deficient Alfisol for gainful yields though higher application of it can be positively beneficial to the crop, albeit, to a small extent. The foliage of the crop was found to be a good aide in turn over of not only native but also applied S as it recorded higher removal of this nutrient when compared to other parts like stems or pod shells. The perceptible increase in total S uptake and use efficiency of applied S from flowering stage to harvest indicated that there is a need to maintain a good supply of S to the crop from flowering stage onwards. This might also need to be investigated with split application of S-supply. The S requirement to the crop was not influenced by the sources through which it was supplied although the use efficiency was slightly higher with gypsum than that of potassium sulphate.

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Relative efficacy of phosphocompost and single super phosphate in soybean, *Glycine max* (L.) Merrill genotypes

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Abstract

A field experiment was conducted during *kharif*, 2001 and 2002 to study the relative efficacy of phosphocompost and single superphosphate in soybean [*Glycine max* (L.) Merrill] genotypes. Application of single super phosphate led to higher yield by 16.2% over phosphocompost, which in turn produced significantly higher yield (19.8%) than no P - control. Among genotypes, JS 335 recorded highest yield, which was higher to the tune of 9.4% over PK 416, 18% over PK 1029 and 21.4% over Ahilya 4. Growth and yield attributes followed the trend similar to that of yield. The highest protein and oil yield were associated with JS 335 followed by PK 416. The maximum protein and oil yield were recorded with the application of single superphosphate. Application of single superphosphate was found the most productive and cost effective source of phosphorus in soybean.

Key words: Phosphocompost, single superphosphate, soybean

Introduction

Optimum and balanced mineral nutrition is of prime importance for higher and sustainable yield (Singh and Nambiar, 1986). Phosphorus is one of the essential elements whose deficiency limits the productivity of soybean. Escalation in market prices of conventional fertilizers (SSP and DAP) restricts the application of this important element by sizeable number of marginal and small farmers. Despite known benefits of manures, bulky nature, high transportation and handling cost, limited availability and low concentration of nutrients restricts their use. Phosphorus enrichment of compost with low grade rock phosphate in association of phosphate solubilizing microorganisms accelerates the process of composting and quality (Singh *et al.*, 1992; Singh, 2000). Insoluble phosphorus could be transformed in to plant available forms during composting and was efficiently utilized by the crops. Moreover, the continues turnover of enriched phosphocompost increased the soil microbial biomass C and activity of enzymes compared to mineral fertilizer (Ghosh *et al.*, 2002) and has been documented as efficient P source for other crops (Singh and Tripathi, 2000). In an attempt to look for economic alternative (Singh and Tripathi, 2000), phosphocompost appeared to be a suitable carrier of P as compared to single super phosphate. Hence, the present investigation was initiated to evaluate the effect of phosphorus sources on productivity and quality of soybean genotypes.

Materials and methods

A field experiment was conducted during *kharif*, 2001 and 2002 on Typic chromusterts to study the comparative efficacy of phosphocompost and single superphosphate in soybean genotypes. The soil of the experimental site belonged to Sarol series, which analyzed: pH 7.6, EC 0.14 d S/m, organic carbon 0.45 %, clay content 56.5%, CaCO3 6.2 %, CEC 51.7 cmol/kg and available phosphorus 13 kg/ha and potassium 180 kg/ha. Two sources of phosphorus *viz*., phosphocompost (4.7% P_2O_5) - the compost enriched with 12.5% rock phosphate and applied @ 2.5 t/ha and single superphosphate (16% P_2O_5) were compared with control and four soybean genotypes *viz*, NRC 37 (Ahilya 4), JS 335, PK 416 and PK 1029 constituted the treatments which were replicated thrice in a Factorial Randomized Block Design. A uniform level of 20:60:20 kg N: P_2O_5: K_2O/ha was applied as basal. Nitrogen and potash were applied through urea and muriate of potash, respectively, while phosphorus was applied through phosphocompost and single superphosphate. Soybean was grown as per recommended package of practices. The observations on plant height and branches and pods/plant were recorded at the time of harvest. The oil and protein content were estimated by non-destructive method using the INFRATECH 1250. The total rainfall received during crop growth period in 2001 and 2002 were 662.6 and 617.4 mm, respectively. The economical parameters were calculated by using the price of phosphorus i.e. Rs 10 kg for phosphocompost (Singh and Tripathi, 2000) and Rs. 18.75/kg for single superphosphate and soybean grain @ Rs.10/kg. The incremental cost, benefit ratio was determined considering the cost of treatment only. The percent response of phosphocompost and single super phosphate was calculated over control in each genotype. The data were pooled over the years and presented.

Results and discussion

Performance of genotypes: The plant growth parameters (plant height, branches/ plant), yield attributes (pods/ plant, seed yield and harvest index) significantly varied among the genotypes. The plants were tallest in Ahilya 4 followed by JS 335. The maximum branches/ plant were in PK 1029, which significantly differed with Ahilya 4 and remained at par with rest. The number of pods/ plant were equal in genotypes Ahilya 4 and JS 335 and both had significantly higher pods/ plant than PK 1029 and PK 416. Genotype JS 335 significantly out yielded the other test genotypes and gave higher seed yield to the tune of 9.4, 18.1, 21.4% over PK 416, PK 1029 and Ahilya 4, respectively (Table 1). The lowest yield was noted with Ahilya 4, which remained at par with PK 1029. JS 335 produced significantly higher straw yield than PK 1029. However, the highest harvest index was obtained with PK 416. Significantly highest protein yield was recorded with JS 335, while the remaining genotypes did not differ significantly. The genotype JS 335 being the maximum in oil yield remained at par with PK 416 (Table 1) and was superior to Ahilya 4 and PK 1029. The differences in yield levels of genotypes may be due to differences in genetic makeup, maturity period and yield potential. Similar results were also reported by Billore and Joshi (1997).

Efficacy of phosphorus sources: The plant height and branches/plant were not influenced by the sources of phosphorus significantly (Table 1). Significantly higher pods/plant were recorded with single superphosphate. Application of single superphosphate facilitated higher yield over phosphocompost (16.2%) and control (39.2%). Phosphocompost in turn produced significantly higher yield (19.8%) than control. The stover yield of soybean was not influenced by the sources of phosphorus. Significantly higher harvest index was associated with single superphosphate. The protein and oil yield were significantly higher with single super phosphate followed by phosphocompost and control (Table 2). The higher yield due to single superphosphate could be due to quick and higher availability of key element P essential in energy transfer during the metabolic processes and its possible role in oil and protein synthesis in the plant. Moreover, super phosphate contains substantial amount of sulphur as compared to phosphocompost. The slow release of P as well as S from phosphocompost could not match the demand of short duration crop like soybean. Although, these results are in agreement with the finding of Billore et al. (2003), equal effectiveness of phosphocompost and single superphosphate (Namdev et al., 2003) and better yield levels (Singh and Tripathi, 2000) than application of single super phosphate have been reported.

Interaction effect of genotypes and phosphorus sources: Interaction of variety and sources of phosphorus was found significant where the highest seed yield was recorded with JS 335 receiving single super phosphate, while the lowest yield was observed with PK 1029 in control (Table 3). From the magnitude of response of phosphorus through different sources as compared to control in various varieties of soybean, it is evident that percent response of soybean genotypes was higher with single superphosphate as compared to phosphocompost irrespective of the genotypes used (Table 4). Among the genotypes, PK 416 followed by PK 1029 responded maximum to single superphosphate and PK 1029, comparatively longer duration variety, to phosphocompost. The single superphosphate was found to be 7.4 to 27% more effective than phosphocompost depending on the variety. This observation is further supported by the incremental B: C ratio and net return over respective control (Table 5).

Table 1 Effect of phosphocompost and single super phosphate on yield and yield attributes of soybean genotypes

Treatment	Plant height (cm)			Branches/plant			Pods/plant			Seed yield (kg/ha)		
	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean
Variety												
Ahilya 4	74	55	65	3	2	2	35	37	36	1573	1181	1377
JS 335	62	49	55	3	2	3	35	35	35	1852	1489	1671
PK 416	51	40	45	3	2	2	29	25	27	1690	1373	1531
PK 1029	53	42	48	3	3	3	26	32	29	1625	1206	1415
CD (P=0.05)	2.78	9.41	4.90	0.31	0.83	0.44	4.09	7.55	4.29	144	74	81
Source of phosphorus												
Phosphocompost	62	48	55	3	2	3	31	31	31	1674	1326	1500
SSP	62	46	54	3	2	3	36	35	36	2096	1389	1743
Control	56	45	51	3	2	2	27	30	28	1284	1221	1252
CD (P=0.05)	2.40	NS	NS	NS	NS	NS	3.55	6.54	3.72	141	64	77

Table 2 Effect of phosphocompost and single super phosphate on straw yield, protein and oil yield of soybean genotypes

Treatment	Straw yield (kg/ha)			HI (%)			Protein yield (kg/ha)			Oil yield (kg/ha)		
	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean
Variety												
Ahilya 4	3031	2651	2841	33.8	30.8	32.3	599.8	474.9	539.4	280.5	192.7	238.2
JS 335	3292	2831	3062	36.4	34.5	35.4	722.8	597.8	661.6	318.0	239.7	278.1
PK 416	2991	2490	2741	36.4	35.5	36.0	621.4	531.2	577.7	298.6	240.5	269.5
PK 1029	2871	2350	2610	35.8	34.4	35.1	656.0	481.8	568.3	271.9	205.7	239.1
CD (P=0.05)	NS	NS	386	5.56	3.92	3.40	74.24	42.66	60.54	15.74	18.67	17.26
Source of phosphorus												
Phosphocompost	3103	2350	2727	32.9	36.1	34.5	647.5	529.6	589.7	292.6	221.0	256.2
SSP	2756	2230	2493	43.4	38.4	40.9	796.1	550.9	676.6	360.5	233.4	296.3
Control	3279	2150	2715	30.5	36.2	33.3	501.7	484.1	492.8	223.2	204.8	213.7
CD (P=0.05)	NS	NS	NS	4.81	3.40	2.95	69.05	37.50	55.56	13.28	15.83	14.61

Table 3 Interaction effect of genotypes and sources of phosphorus on seed yield (kg/ha) of soybean

Genotype	Year	Phosphocompost	Single super phosphate	Control	Mean
Ahilya 4	2001	1573	1802	1344	1573
	2002	1249	1228	1068	1181
	Mean	1411	1515	1206	1377
JS 335	2001	1858	2208	1489	1852
	2002	1513	1545	1410	1489
	Mean	1685	1877	1450	1671
PK 416	2001	1638	2263	1171	1690
	2002	1345	1524	1249	1373
	Mean	1491	1893	1210	1531
PK 1029	2001	1130	2113	1131	1625
	2002	1198	1259	1158	1206
	Mean	1414	1686	1145	1415
Mean	2001	1674	2096	1284	
	2002	1326	1389	1221	
	Mean	1500	1743	1253	
CD (P=0.05)	2001	282.40			
	2002	127.78			
	Mean	154.98			

Table 4 **Magnitude of response of soybean genotypes to single super phosphate and phosphocompost (mean of 2001 and 2002)**

Variety	Response over control (%)		Response to SSP over phosphocompost (%)
	Single super phosphate	Phosphocompost	Single super phosphate
Ahilya 4	25.6	17.0	7.4
JS 335	29.4	16.2	11.4
PK 416	56.5	23.3	27.0
PK 1029	47.3	23.5	19.2

Table 5 Economic analyses of sources of phosphorus and soybean genotypes (mean of 2001 and 2002)

Treatment	Character	Phpsphocompost (Cost= Rs. 600/ha)	Single super phosphte (Cost= Rs. 1125/ha)	Control	Mean
Ahilya 4	Gross returns (Rs/ha)	2046	3093	-	2570
	Net returns (Rs/ha)	1446	1968	-	1707
	B:C ratio	3.41	2.74	-	3.08
JS 335	Gross returns (Rs/ha)	2354	4269	-	3312
	Net returns (Rs/ha)	1754	3144	-	2449
	B:C ratio	3.92	3.79	-	3.86
PK 416	Gross returns (Rs/ha)	2815	6833	-	4824
	Net returns (Rs/ha)	2215	5708	-	3962
	B:C ratio	4.69	6.07	-	5.38
PK 1029	Gross returns (Rs/ha)	2692	5412	-	4052
	Net returns (Rs/ha)	2092	4287	-	3190
	B:C ratio	4.48	3.81	-	3.74
Mean	Gross returns (Rs/ha)	2476	4902	-	-
	Net returns (Rs/ha)	1876	3777	-	-
	B:C ratio	3.12	4.35	-	-

The economic analysis also revealed the superiority of single superphosphate over phosphocompost as evidenced from the higher values of net returns and incremental B: C ratio. The highest net returns and B: C ratios were accrued in PK 416 fertilized with single super phosphate followed by PK 416 receiving phosphocompost.

On the basis of foregoing results it may be concluded that the application of phosphorus through single super phosphate was more productive and effective in soybean raised on Vertisols of Madhya Pradesh.

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A data management system for plant breeding network of All India Coordinated Research Project on Soybean

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Abstract

The data management system developed at National Research Centre for Soybean (NRCS) for All India Coordinated Research Project on Soybean (AICRPS) experimentation provides routine processing of data and production of summary table reports in easy, efficient and user-friendly manner. It has a special feature of on-line data-entry allowing users the flexibility to enter/edit the data from any place provided they have internet connectivity. The main system is developed using Visual Basic (6.0) and the on-line data-entry system using web technologies *viz.* Hyper Text Mark up Language (HTML) and ASP (Active Server Pages). The database at back end is designed using SQL Server 2000 relational database. The reports are generated in the form of EXCEL worksheets. The system is described and the extent to which it has met its objectives is discussed, with emphasis on the requirements of t he end-user.

Key words: Breeding, data management, software, soybean

Introduction

Soybean is the most important and valuable oilseed crop of the world. India ranks fifth in the area (5.68 m ha) and production (4.30 mt) of soybean in the world after USA, Brazil, Argentina and China. Recognizing the potential of soybean in meeting the present and future needs of the country for vegetable oil and protein rich food, the Indian Council of Agricultural Research(ICAR) launched a multi-locational inter-disciplinary All India Coordinated Research Project on Soybean (AICRPS) in 1967. This network project has 7 main centres, 13 sub-centres and 8 need-based centres representing different agro-climatic regions of the country. The co-ordinating unit for the project, National Research Centre for Soybean (NRCS), Indore, a constituent of Indian Council of Agricultural Research provides centralized support to the production system research with basic technologies and breeding material of soybean (*Glycine max* L. Merrill). This multidisciplinary and multi-locational project has been catering the need of the country with respect to crop improvement, crop production and crop protection aspects. Of the activities envisaged under the project over 70% share comes from crop improvement programme. The experimentation covers five zones namely North Hill, North Plain, North eastern, Central and Southern. Every year, a sizeable data is generated from each cooperative centre and its manual compilation was in vogue. Moreover, it was cumbersome to lay hands on data generated over years. This process of compilation and report generation was time consuming, laborious and is prone to human error.

The drudgery involved in the manual procedure followed every year for AICRPS summary table report preparation, warrants for development of a system which would make summary table report generation more rapid by reducing delays in data input and provide the users with a simple, easy-to-handle, user-friendly method to retrieve accurate and efficient report production for varietal performance decisions to be taken in Annual Workshop of AICRPS. The first stage of this work, the development and introduction of a preliminary version (Using FOXPRO) of a computer system for compilation of data and report generation was introduced in 1998. The final stage of the development, the replacement of the outdated database structure by SQL SERVER 2000 database holding AICRPS plant breeding trial data along with an internet based on-line data-entry system linked to the institute website (www.nrcsoya.com) and a NRCS based computerized data management system for summary table report generation and maintaining historic data, has taken five man-years. Similar efforts on data management systems have earlier been documented (Wallach and Rellier, 1987, Martiniello, 1988 and Bayles and McCall, 1995).

This paper describes the NRCS data management system for AICRPS plant breeding trials and discusses ways in which it has benefitted one typical group of users, the plant breeders.

Keeping this in view, a study was undertaken with the following objectives:

1. To ensure that the routine processing of trial data and production of reports are carried out in an efficient and effective way thus significantly reducing the time and drudgery involved in-

- Compilation of AICRPS plant breeding trial data obtained from different AICRPS centres.
- Preparation of yearly summary table reports.

2. To computerize the whole manual procedure by developing a user-friendly system.
3. To provide all muti-locational users with facilities for on-line data-entry into the database to ease the work of compilation of huge data.
4. To allow safe storage of, and easy access to performance data for varieties.

Data collection

The research on soybean improvement and identification of better varieties to suit varied location specific requirements of different regions of the country is being continued. Improved lines/material developed as a result of breeding efforts at different centres are evaluated in three tier system consisting of (i) Initial Varietal Trial (IVT) (ii) Advanced Varietal Trial-I (AVT-I) and (iii) Advanced Varietal Trial-II (AVT-II). These trials are conducted across the country in five zones *viz.* Northern Hill, Northern Plain, Central, Southern and North-eastern zones. The performance of test varieties for a particular zone in each trial are compared against a few check varieties in terms of 'Rank' assigned based on the variety-wise 'Mean'. Only those varieties, which perform better with respect to yield performance than the check varieties in a particular zone, are promoted to the next tier in the 3-tier testing system. So, the data, collected on various performance parameters on each trial by the coordinated centres spread all over the country at different locations of five zones, is compiled at the NRCS and summary table reports are prepared every year.

Description of the system

The overall computerized system is user-friendly and interactive and has been designed in such a manner that even a person with limited computer skills can handle it easily. The main system is developed using Visual Basic and the on-line data-entry system is developed using web technologies *viz.*, Hyper Text Mark up Language (HTML) and ASP (Active Server Pages). The database at back end is designed using SQL Server 2000 relational database. The reports are generated in the form of EXCEL worksheets. The total software size is 15 MB.

The main user-interface is provided in the form of Menu-bar with menu options *viz.*, 'Master', 'Data-entry', 'Report', 'User-settings', 'Logout' and 'Help' as shown in Fig. 3. Each of these menu options has a few sub-menu options which when clicked will open a certain form to perform certain task. In 'Master' Menu, Master entries viz. zone, trial, character and location are done with their respective entry-forms. The Variety list for a particular zone and trial is entered through 'Variety-Information' form that is available to the user by clicking 'VarietyList' sub-menu option of 'Data-entry' main menu option. The user can do the local data entry through 'Data-Entry' form and subsequently the reports can be generated by using 'Report' form.

The complete database comprises of eleven tables along with their respective fields viz., Zone (zone_id, zone_name), Trial (trial_id, trial_name), Character (character_id, character_name), Location (location_id, location_name, zone_id), Variety (variety_id, variety_name, zone_id, trial_id), Main_Data (id_code, variety_id, data), Idtable (id_code, location_id), Footer_data (id_code,trial_id, nps, cd, cv, dos), Login (user_name, password), Online User (user_id, user_name, password) and Permissions (user_id, location_id). The database size without insertion of data is nearly 2MB and with insertion of the data from all the locations, the size becomes 170MB or more depending on the number of varieties in each trial every year. The logical operation of the system can be described with the data flow diagram as shown in Fig.1. It shows the flow of data through the system and the work or processing performed by the system.

The whole system design can be viewed with the Entity-Relationship (E-R) diagram as shown in Fig. 2. The ER-model is a conceptual data model of the system. The diagram shows the kind and organization of the data that is stored in the database.

The stages while operating the system are as follows.

Preparation of the system as per the technical programme

The system needs to be prepared to get it ready before starting data compilation and report generation tasks as follows.

1. Initially all the zone names, trials, characters and zone-wise location list are to be entered using the "Master" menu-option of the main interface as shown in Fig. 3.
2. Every year as per the technical programme for that year variety list is entered based on zone and trial by using "variety-list" option of "data-entry" main menu-option. Out of all the varieties some are indicated to be check variety. These are of special importance to the plant breeders while taking Varietal performance decisions during annual AICRPS workshop. IVT entries are displayed in the form of variety-code on on-line data-entry system.

Thus all the master tables of the database are made ready for subsequent functionality of the package.

Zone-wise and trial-wise data compilation and manual data entry

Every year, after the cropping season, all the AICRPS in-charges of different centres send the data in printed sheets. These sheets are sent through post to the main-coordinating centre, NRCS. These sheets are compiled zone-wise by the coordinators at NRCS. These zone-wise packets of data are then given to the data-entry operator for entry in the system. The operator can do new data-entry, change the existing data or delete the data by using different menu-options provided in the package.

Web-based data entry

Alternatively, the AICRPS in-charges of different centres also have option to do data-entry on their own at their locations instead of sending the printed sheets through post. This is possible using the on-line data-entry system linked to the NRCS website. The in-charges have separate user-name and passwords so that they are allowed to enter, edit and access the data of their location only. The data thus entered is stored on remote server, might be appended to the final database at NRCS-based local server before report generation. This not only saves the time for getting final data but also reduces the burden of huge volume of data handling on coordinators at NRCS.

Processing of data files

The database is transferred from the remote server to the local (NRCS-based) server for local data-entry and data processing. After the completion of data-entry, correction of erroneous data, validation of the final data and before the generation of reports, the data files are processed at the system level for calculation of variety-wise mean, location-wise mean (for yield character) and varietal performance ranking. Based on these ranks as shown in the final reports, decisions on better performance of varieties are taken.

Efficient error handling

The system has been designed in such a way that data-entry operator is not given any chance to commit any error. The user interface is such that most of the inputs are provided to the system through selections from a list with more than one valid option. Efficient error handling procedures are used so that if, by any chance, any wrong entry is done, it will alert the user by promptly producing error messages. The user interface is such that even a novice user with less computer skills can also handle the system comfortably.

Data analysis and Report generation

After the completion of the data-entry and processing tasks, the summary table reports for each zone and trials for all characters are taken out. The printed computer reports for all the zones are scrutinized briefly by data processing staff for recording errors that have not been trapped by validation at the input stage. This is done by physically matching the data on computer-generated reports to the original data sheets. The erroneous jobs are edited by them and submitted for rerunning. The reports again generated are then referred to the trials coordinators for subsequent correction at their stage. After complete correction of errors at different levels by coordinators, final reports are produced in formats specified by the AICRPS coordinators using, where possible, computer procedures, which will produce reports in a standard format. More complex and non-standard reports are produced using a combination of report generation menu-option and word-processing viz. MS-Word and spread sheet packages like MS-Excel. This provides a more versatile approach to report production than customized computer procedures.

Creating history database files

Looking for the safety of overall database and its easy access after a long period of gap as and when required, system has a provision to create history database files. The complete database with all the tables in it can be stored in the form of backup files, which can be restored and linked to the system, as and when required for getting information, in future. The structure of the history databases is same as the original database when it is restored from the backup files.

Monitoring all the phases of the system

The System administrator can give access rights to different breeders with different permissions as an administrator and data-entry-operator. The administrator monitors every phase of the system from Master table data-entry as per the technical programme up to final report generation.

A plant breeder's view of the system

Efficient handling of huge volume of data

NRCS plant breeders based at AICRPS main coordinating centre, are responsible for coordinating large breeding programmes of trials designed to evaluate best performing soybean varieties. Soybean varieties are assessed in different trials throughout the India by local trials' in-charges. These variety trials include assessments on performance parameters *viz.* yield (kg/ha), 100 seed weight (g), days to maturity, days to flowering and plant height (cm). These trials are conducted every year in more than 5000 plots with more than 10 records being taken on each plot. This leads to the generation of huge volume of data. The breeders found that the system is highly efficient to handle such a huge volume of data producing accurate results.

Data-entry irrespective of the location through on-line data-entry system

The AICRPS officers at different locations appreciated the feature of on-line data-entry as they can easily enter, their location specific data, at their places thus reducing the cost and delays through postal mails. Also, coordinators at NRCS can easily download the data from remote server to the local NRCS-server thus reducing the time involved in data compilation and then data-entry at the headquarters.

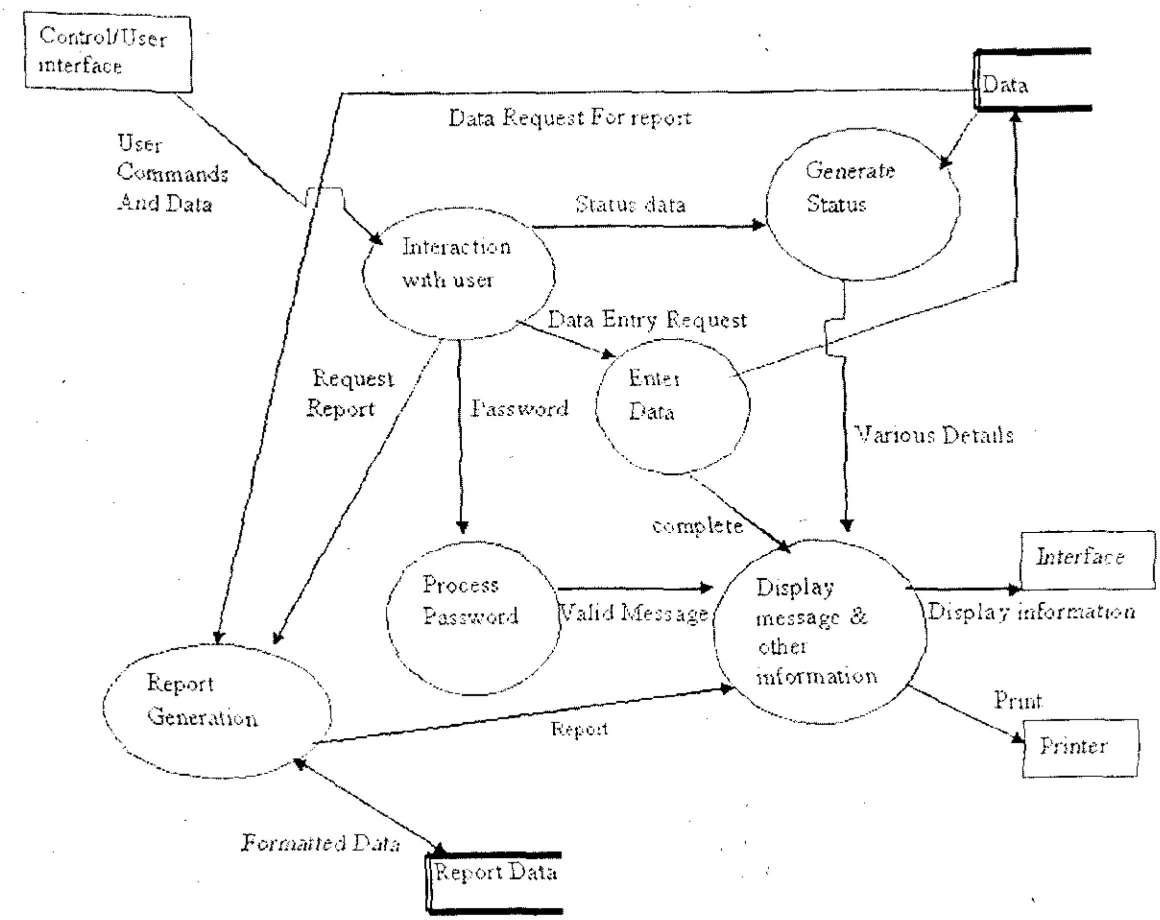

Fig. 1 Data flow diagram (DFD) of the system

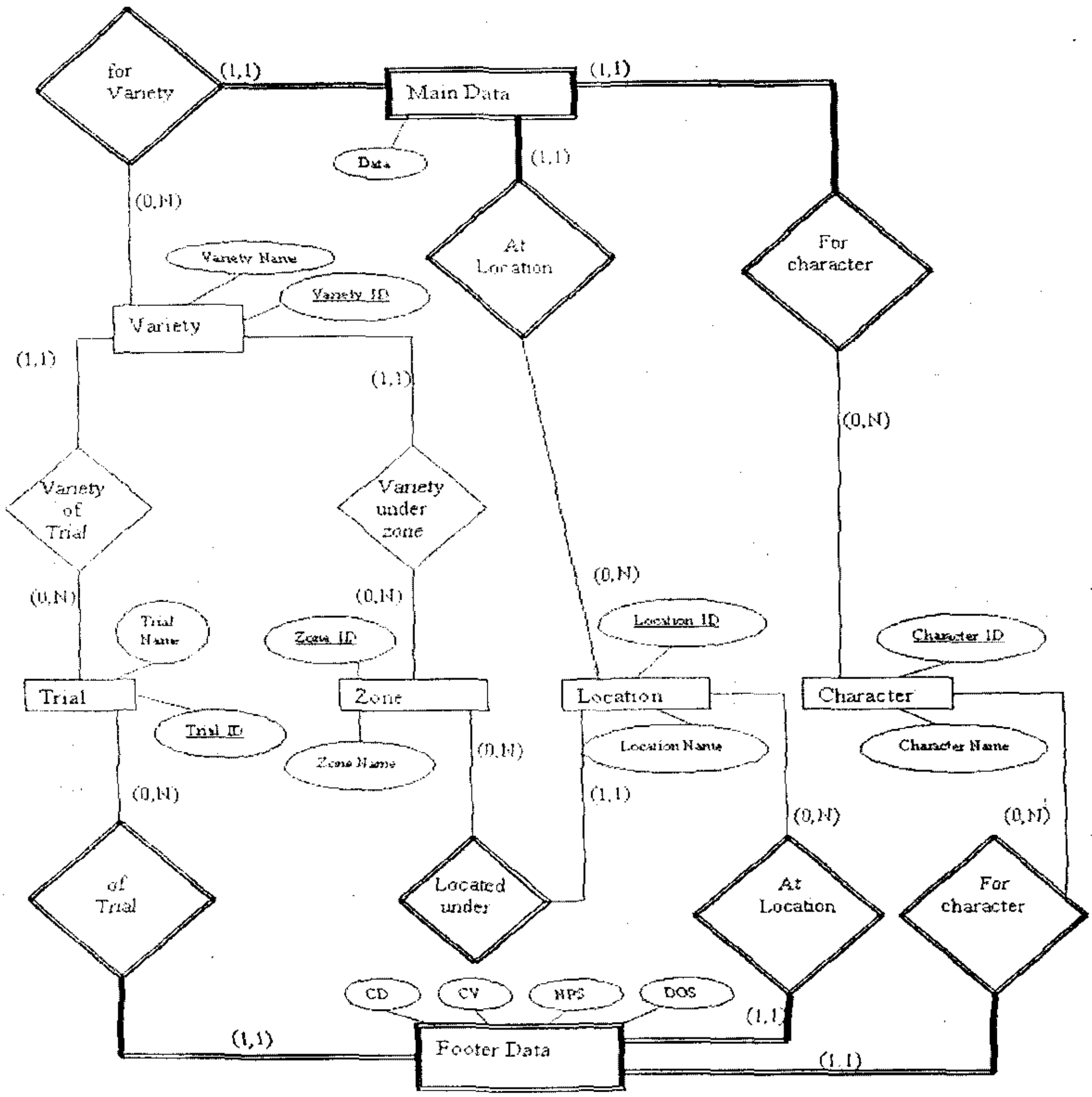

Fig. 2 Entity-relationship (E-R) diagram of the system

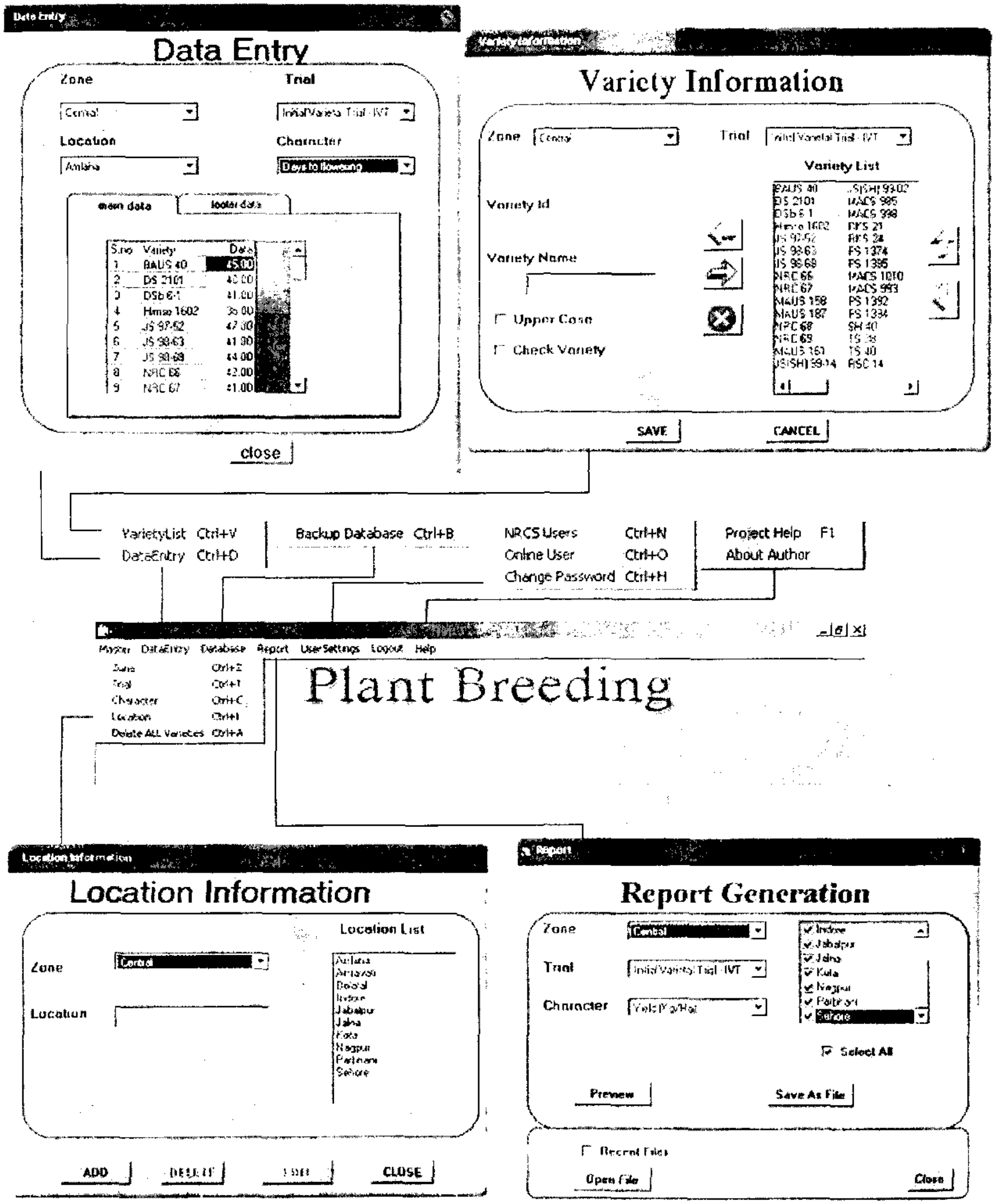

Fig. 3 Detailed design of the Graphical User Interface of the system

Accurate and uniform report generation

The system uses efficient procedures for rapid calculation of mean and rank, so that users get accurate results. The reports generated earlier through typewriters were not uniform. Now, the breeders are happy to get uniform reports with same fonts and style thus making the overall summary table report attractive and occupying less space thus reducing the overall cost of printing.

Access to historic data

Every year huge volume of performance trial data is generated which is kept in the form of historic data files at NRCS server. Since, versatile clientele for research purposes requires this data, it can be easily made available. Due to institute's policy the data is not made available online but can be obtained from the center. Even if the printed copy of the report is not available, the report of the past years can be easily generated with the help of the system. Thus, history data files provide safe and secured structure for preserving the important past data.

Results and discussion

In general, the aims of the system have been achieved. It took many hours of rigorous analysis, planning, discussion, designing, programming and user effort that have contributed towards its successful development.

The introduction of the new system has resulted in following benefits.

- The manpower involvement has been drastically curtailed, as compared to the earlier system.
- Resulted in more accuracy of the results, with a reduction in the number of data-entry errors at the headquarter for processing.
- Speeded up the availability of AICRPS trials data to the coordinators, plant breeders and other agricultural researchers.
- Reduced the cost of the routine data processing and streamlined the processing of the data.
- Reduced considerably the quantity of data sheets received and handled at NRCS.
- Produced a system that has fulfilled the requirements of the plant breeders as well as soybean researchers working on Varietal performance parameters.
- Produced a more flexible and user-friendly means of retrieving multilocational performance information reports for soybean varieties.

The system was rigorously tested by putting live data and proved to be accurate with full satisfactory report format. Rapid acceptance and implementation of the computerized system of trial data handling and report generation, was achieved with the help of thorough training to all the users. The awareness of the availability of on-line submission of the data from different cooperating centres has already been created. Some of the centres are attempting to utilize the same and others are being motivated. The data so received on remote server is down loadable on the local server and subsequently updated with the data received in the form of hard sheets from some of the Centres, which do not have the Internet facility. This proactive action and utilization of facility by all the centres shall lead to real success of the soft ware developed.

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Hybrid vigour and combining ability in sunflower, *Helianthus annuus* L. hybrids involving CMS lines

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Abstract

Thirty crosses generated from five cytoplasmic male sterile lines of sunflower and six restorers in a line x tester design and their parents were evaluated for general and specific combining ability, variance components and standard heterosis. Predominance of non-additive gene action was observed for all the traits studied, though additive gene action was also found to be operative. The parents DCMS 18, DCMS 5, DSI 15 and DRS 16 were proved to be good general combiners for yield and most of its related characters. Nine crosses namely DCMS 34 x DRS 22, DCMS 18 x DSI 15, DCMS 18 x DSI 9, DCMS 18 x DSI 86, DCMS 24 x DRS 16, DCMS 24 x DRS 22, DCMS 5 x DSI 9, DCMS 5 x DRS 16 and DCMS 12 x DSI 86 had shown higher significant positive *sca* effects for seed yield/plant. The estimated standard heterosis ranged from -20.32 to 8.80%. Out of 30 combinations, only four crosses (DCMS 18 x DSI 15, DCMS 18 x DSI 86, DCMS 24 x DRS 16 and DCMS 5 x DRS 16) registered positive significant standard heterosis for seed yield/plant.

Key words: Sunflower, cytoplasmic male sterility, combining ability, hybrid vigour

Introduction

Sunflower, the second major oilseed crop, forms a potential source of vegetable oil and protein. The discovery of cytoplasmic male sterility (Leclercq, 1969) and subsequent identification of restorers (Kinman, 1970; Enns *et. al.*, 1970) have significantly contributed in genetic improvement of the crop as well as in exploitation of heterosis, leading to development and release of several hybrids for commercial cultivation. From 1972 to till today several hybrids have been developed by using a single male sterile source, PET1, which widens the scope for its vulnerability to any strain of disease or insect pests in epidemic form. Hence several new diverse cytoplasmic male sterile sources were identified but only few effective restorer lines were identified for these CMS sources. To develop sunflower hybrids with improved yield potential, the choice of parents through careful and critical evaluation is of paramount importance. Combining ability studies elucidates the nature and magnitude of gene action involved in the inheritance of character by providing the information on the two components of variance *viz.*, additive genetic and dominance variance, which are important to decide upon the parents and crosses to be selected for eventual success. Such information is required to design efficient breeding programme for rapid crop improvement. Accordingly, the present investigation was undertaken to have an idea on the nature of gene action involved in inheritance of important quantitative traits and to select the parents with good *gca* and crosses with good *sca* effects through line x tester analysis in sunflower.

Materials and methods

Five cytoplasmic male sterile lines (DCMS 34, DCMS 18, DCMS 24 and DCMS 5) and six restorers (DSI 15, DSI 9, DSI 86, DSI 57, DRS 16 and DRS 22) were planted at Directorate of Oilseeds Research, Hyderabad. Crossing was performed in line x tester fashion among the CMS lines and restorers. Seed was collected to study the combining ability analysis in the next season.

During *rabi* season, 30 hybrids along with parents were sown in a Randomized Complete Block Design replicated thrice with a row length of 5 m. Spacing was adopted as 60 cm between rows and 30 cm between hills. Observations were recorded on five randomly selected plants in each replication to record data on the following characters *viz.*, days to 50% flowering, days to maturity, plant height, number of leaves/plant, head diameter, 100-seed weight, number of seeds/plant, oil per cent and seed yield/plant. The data were subjected to combining ability analysis and estimation of variance components (Kempthorne, 1957) and heterosis (Hays *et. al.*, 1955).

Results and discussion

Analysis of variance for combining ability revealed that mean squares due to lines were significant for all the characters except head diameter while mean squares due to testers were significant for six characters excluding days to 50% flowering and number of leaves/plant (Table 1). The mean squares due to line x tester interaction was significant for all the characters except number of leaves/plant. Thus, the variation in hybrids in respect to different traits is due to significant variation among parents used in developing the hybrids.

The estimates of variances for general and specific combining ability indicated that *sca* variance was high reflecting greater role of non-additive type of gene action in expression of these traits. The degree of dominance was more than unity for all traits studied confirming the above inference. Similar findings were reported by (Kumar *et. al.*, 1997; Satyanarayana, 2000; Krishna, 2001).

The estimates of *gca* effects of the parents (Table 2) revealed that among female lines, DCMS 18 and DCMS 5 showed significant and positive *gca* effects for seed yield/plant. DCMS 18 was also good general combiner for number of leaves/plant, head diameter and test weight. DCMS 5 recorded significant *gca* effects for days to 50 % flowering, days to maturity, plant height, test weight and oil content. The female lines DCMS 5 and DCMS 12 recorded desirable general combining ability for important economic trait i.e., oil content. DCMS 5 was the best general combiner for earliness in flowering and maturity. Among the testers, DSI 15, DSI 9 and DRS 16 were found to be good general combiners for seed yield/plant. Of these DSI 15 also registered to be a good combiner for days to 50 % flowering, days to maturity, plant height, head diameter and oil content, while DSI 9 for test weight and DRS 16 for plant height, number of leaves/plant and test weight. The testers, DSI 15 and DSI 57 were found to be good general combiners for earliness. Thus, the parents DCMS 18, DCMS 5, DSI 15 and DRS 16 exhibited favorable *gca* effects for most of the important traits. These parents may extensively be used in important programme so that the optimum combinations of these components can be obtained which is necessary for achieving high yield levels.

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

	Degrees of Freedom	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of leaves/ plant	Head diameter (cm)	100 Seed Weight (g).	Oil (%)	Seed yield/ plant (g)
Replications	1	14.02	2.4	125.06	0.379	0.113	0.58	19.49	25.43
Lines	4	16.68*	28.48**	792.62**	43.89**	1.27	2.37**	125.81**	112.56**
Testers	5	9.09	29.67**	642.01**	13.34	4.08*	1.13**	105.75**	54.50**
Line x Tester	20	12.06**	18.51**	223.76**	13.95	3.75*	1.18**	47.35**	75.3**
Error	29	4.46	5.4	56.79	8.05	1.36	0.203	9.94	8.73
GCA		0.075	0.96	44.86	1.33	0.047	0.051	6.22	0.74
SCA		3.8	6.56	83.48	2.95	0.39	0.49	18.7	33.28
SCA/GCA		*50.67*	*6.833333*	*1.860901*	2.218045	*8.297872*	*9.607843*	*3.006431*	*44.97297*
SCA/2GCA		5.033223	1.848423	0.964599	1.053101	2.036894	2.191785	1.226057	4.741992

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

Line DCMS 5 and two testers DSI 9 and DSI 15 were found good general combiners for seed yield, earliness and high oil content and could effectively be used in breeding programmes aimed at earliness and high yield. Rao and Singh (1977) observed that no parent was found to contain all the favourable or unfavourable genes for all the characters, as is the case of present study. In contrast a parent showing high *gca* effects for component traits is not necessarily a good general combiner for grain yield i.e., inbreds with some of the desirable traits also possessed certain undesirable traits.

The estimates of *sca* effects of nine crosses *viz.*, DCMS 34 x DRS 22, DCMS 18 x DSI 15, DCMS 18 x DSI 9, DCMS 18 x DSI 86, DCMS 24 x DRS 16, DCMS 24 x DRS 22, DCMS 5 x DSI 9, DCMS 5 x DRS 16 and DCMS 12 x DSI 86 showing significant positive values for grain yield are presented in Table 3. Of the nine crosses only four crosses *viz.*, DCMS 34 x DRS 22, DCMS 18 x DSI 15, DCMS 24 x DRS 22 and DCMS 5 x DRS 16 recorded significant positive *sca* effects for oil content also.

The crosses DCMS 18 x DSI 15 and DCMS 5 x DRS 16 recorded significant sca effects for plant height, DCMS 34 x DRS 22 and DCMS 24 x DRS 22, for number of leaves/ plant, DCMS 18 x DSI 9, DCMS 18 x DSI 86, DCMS 5 x DSI 9 and DCMS 5 x DRS 16 for head diameter, DCMS 34 x DRS 22, DCMS 18 x DSI 15, DCMS 24 x DRS 22 and DCMS 5 x DRS 16, for oil content recorded significant positive *sca* effects It was observed that the crosses with significant desirable *sca* effects for higher yields did not show good *sca* effects for all yield-attributing components.. None of the cross which was good specific combiner for yield significant *sca* effects for all the traits. The crosses with significant *sca* effects for different traits did not involve both the parents with significant *gca* effects. It involved combinations with high x low or low x low or low x high *gca* effects. Inspite of the involvement of both poor general combiners or one of the parent as poor general combiners, these cross combinations expressed significant *sca* effects in desirable direction which might be due to concentration and interaction between favourable genes contributed by the parents. Singh *et. al.*, (1999) and Krishna (2001) also observed the involvement of high x low *gca* combinations of parents for crosses with high *sca* effects.

The estimation of standard heterosis ranged from -20.32% (DCMS 34 x DSI 57) to 8.80% (DCMS 18 x DSI 86). Out of thirty combinations, only four crosses (DCMS 18 x DSI 15, DCMS 18 x DSI 86, DCMS 24 x DRS 16 and DCMS 5 x DRS 16) registered positive significant standard heterosis for seed yield/plant. These cross combinations also showed significant *sca* effects for yield and involved either seed or pollen parent with high *gca* effects.

Therefore it can be concluded in the present investigation that all the characters were governed by non-additive gene action. The cross combinations showing high *sca* effects for yield and its related traits, if found to be a combination of one or both parents having good general combining ability can be utilized in the hybrid development programme for exploitation of hybrid vigour through diversified restorer systems to raise the yield levels of sunflower.

Table 2 General combining ability effects of parents for yield and other traits in sunflower

	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of leaves/ plant	Head diameter (cm)	100 Seed Weight (g)	Oil (%)	Seed yield/ plant (g)
Line								
DCMS 34	1.02*	0.87	2.24	-0.49	0.17	-0.06	-2.59*	0.01
DCMS 18	1.27*	0.28	-3.75	2.91**	0.48*	0.36**	-1.43	3.01**
DCMS 24	-0.32	-1.38*	-11.31**	-0.83	-0.36	-0.64	-2.53*	-5.09**
DCMS 5	-1.65**	-1.72**	10.59**	-2.2*	-0.18	0.48**	1.65*	1.34*
DCMS 12	-0.32	1.95**	2.24	0.6	-0.1	-0.14	4.91**	0.73
Tester								
DSI 15	-1.72**	-2.30**	5.24*	0.92	0.94*	-0.34	2.02**	3.90**
DSI 9	0.18	-0.3	-14.34	-0.49	0.09	0.43**	-0.84	1.80**
DSI 86	-0.12	-1.2	-0.57	-0.33	-0.39	0.21	-1.37	-0.78
DSI 57	-1.18**	-2.70**	-2.35	-1.54	-0.87	0.42	-2.02	-3.15**
DRS 16	0.08	0.3	3.84*	1.74**	0.45	-0.07	-3.35	1.68**
DRS 22	0.38	0.8	8.2	-0.28	-0.2	0.2	5.56	-1.99**

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

Table 3 Specific combining ability effects in the crosses for seed yield and component traits in sunflower

Cross combinations	Seed yield/ plant (g)	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of leaves/ plant	Head diameter (cm)	100 Seed Weight (g).	Oil (%)
DCMS 34 x DRS 22	10.24**	-2.22*	-0.47	5.94	2.85**	-0.76	1.72**	3.62*
DCMS 18 x DSI 15	4.26**	1.79	0.72	9.64*	0.73	0.19	0.34	3.79*
DCMS 18 x DSI 9	3.38**	-2.27*	-3.38**	0.27	0.34	1.21*	0.38	-4.5*
DCMS 18 x DSI 86	6.19**	3.08*	1.12	2.15	-2.27*	1.33*	0.50*	-4.2*
DCMS 24 x DRS 16	5.62**	-2.58	-2.72	3.50	1.21	0.77	0.02	2.16
DCMS 24 x DRS 22	3.01*	-3.38	-4.22**	-2.16	3.09**	0.87	-0.65**	3.75*
DCMS 5 x DSI 9	5.2**	0.32	0.96	-0.52	1.28	1.38*	0.14	0.87
DCMS 5 x DRS 16	7.67**	0.42	0.45	8.10*	1.17	1.64**	0.75**	4.43**
DCMS 12 x DSI 86	3.62*	-2.05	-0.88	-6.44	0.02	0.40	0.24	-2.66

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

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Genetic divergence for seed yield and its component traits in sunflower, *Helianthus annuus* L. germplasm accessions

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Abstract

In order to assess the genetic divergence among the 102 genotypes consisting of 100 germplasm accessions and two released varieties in sunflower, Mahalanobis D^2 statistics was applied. The analysis of variance revealed significant differences among the genotypes for all the traits. The 102 genotypes were grouped into 12 clusters where, cluster I was largest containing 51 genotypes followed by cluster II with 26 genotypes, cluster XI with ten genotypes and cluster VII with seven genotypes. The inter cluster distance was maximum between cluster XI and XII, followed by cluster VIII and IX and cluster IV and XI. Based on the inter cluster distance and *per se* performance of genotypes, the entries *viz.*, GMU-4, GMU-11, GMU-14, GMU-16, GMU-25, GMU-40 and GMU-70 were selected which could be intercrossed to obtain high heterosis and also to recover desirable transgressive segregants. Seed yield/plant contributed maximum divergence (40.2%), which was followed by number of leaves/plant (25.8%) and hundred seed weight (17.0%).

Key words: Sunflower, genetic divergence, D^2 statistics

Introduction

Sunflower is an important edible oilseed crop of the world. The crop is grown under diverse agro-production situations, crossing climatic and geographic boundaries, which necessitated the development of more productive hybrids of diverse duration. Development of Hybrid is of much value for increasing the production of sunflower. For efficient hybridization programme, selection of genetically diverse parents and superior genotypes is a pre-requisite, which ensures high heterosis and exhibit a gamut of transgressive segregants in order to increase the productivity levels of sunflower. The present study was an attempt to know the magnitude of diversity present in different germplasm accessions for yield and yield related component traits.

Materials and methods

The material for the present study consisted of 100 sunflower germplasm accessions from GMU-01 to GMU-100 two checks *viz.*, DRSF-108 and Morden. The experiment was conducted at Directorate of Oilseeds Research, Hyderabad during *kharif*, 2004. Each accession was sown in five rows of 3 m length with a spacing of 60 cm between row 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 (cm), leaf lamina width (cm), petiole length (cm), days to 50% flowering, days to maturity, plant height (cm), number of leaves/plant, head diameter (cm), per cent seed filling, 100 seed weight (g), seed yield/plant and oil content (%). The data was subjected to statistical analysis using Mahalanobis D^2 Statistics (Mahalanobis, 1936) and Toucher's method as described by Rao (1952) for determining group constellation. Average intra and inter cluster distances were estimated as per the procedure outlined by Singh and Chaudhary (1977).

Results and discussion

The analysis of variance revealed significant differences among the genotypes for all the traits studied. Based on D^2 statistics and Tocher's method the 100 germplasm accessions along with two released varieties can be grouped into 12 clusters however, with variable number of entries in each cluster revealing considerable amount of genetic diversity in the material (Table 1). It was observed that cluster I had the maximum number with 51 genotypes followed by cluster II with 26 genotypes, cluster IX with 10 genotypes and cluster VIII with seven genotypes. The four clusters I, II, VIII and IX together included 94 genotypes reflecting narrow genetic diversity among them. The narrow genetic diversity may be attributed to similarity in the base material from which they have been evolved. Further, clusters III, IV, V, VI, VII, X, XI and XIII were found to be solitary clusters. However, lines derived from the same source of parentage were grouped in different

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clusters demonstrating the impact of selection pressure in increasing the genetic diversity. The checks Morden and DRSF-108 were included in cluster II and IV respectively indicating their distinctness or similarity from the germplasm accessions with respect to traits considered. Similar results have been reported by Teklwold *et al.* (2000) and Vishnuvardhan Reddy and Devasenamma (2004) in sunflower.

Average intra and inter cluster D^2 values among 102 genotypes (Table 2) revealed that cluster V had the minimum intra cluster value (8.5) indicating that genotypes within this cluster were similar. While, cluster VIII showed the maximum intra cluster D^2 value (26.4), followed by cluster II (23.1) and cluster I (22.4) revealing there by the existance of diverse genotypes that fell in these clusters. The inter cluster D^2 values ranged from 8.3 to 63.9. Minimum inter cluster D^2 values were observed between cluster III and V indicating the close relationship among the genotypes included in these clusters. Maximum inter cluster value was observed between XI and XII (63.9) followed by cluster VIII and XI (57.3) and cluster IV and XI (55.9) which indicates that genotypes included in these clusters are genetically diverse and may give rise to high heterotic response.

The cluster means and contribution of each trait towards genetic divergence are presented in Table 3. The data revealed considerable differences among the clusters for most of the characters studied. The cluster IX (GMU-01, GMU-24, GMU-30, GMU-32, GMU-43, GMU-52, GMU-53, GMU-60, GMU-90 and GMU-93) recorded highest seed yield/plant and oil content, where as cluster XI (GMU-40) recorded highest mean hundred seed weight (6.5g), number of leaves/plant (39.3) and plant height (177 cm). The cluster X recorded lowest hull percent (19.0%), where as, cluster VII recorded the highest percent seed filling (76.3) and leaf lamina length (27.6 cm). The cluster XII recorded lowest mean days to 50% flowering (44 days) and highest petiole length (19.6 cm).

Table 1 Distribution of 100 germplasm accessions along with two checks into 12 clusters based on D^2 values

Cluster	Number of accessions	Accessions
I	51	GMU - 02,GMU - 05, GMU - 17,GMU - 18, GMU - 19, GMU - 22,GMU - 27, GMU - 29, GMU - 31, GMU - 33, GMU - 34, GMU - 35,GMU - 36, GMU - 37, GMU - 38, GMU - 39, GMU - 45, GMU - 47, GMU - 48, GMU - 50, GMU - 51, GMU - 55, GMU - 56, GMU - 57, GMU - 59, GMU - 65, GMU - 67, GMU - 69, GMU - 71, GMU - 72, GMU - 73, GMU - 74, GMU - 75, GMU - 76, GMU - 77, GMU - 78, GMU - 79, GMU - 80, GMU - 81, GMU - 82, GMU - 83, GMU - 84, GMU - 85, GMU - 87, GMU - 88, GMU - 89, GMU - 94, GMU - 95,GMU - 97,GMU - 98, GMU - 100
II	26	DRSF - 108,GMU - 03,GMU - 06,GMU - 07,GMU - 08,GMU - 10, GMU - 12,GMU - 13,GMU - 15,GMU - 20, GMU - 21,GMU - 26, GMU - 28,GMU - 41,GMU - 42,GMU - 44,GMU - 46,GMU - 49, GMU - 54,GMU - 62, GMU - 63,GMU - 64,GMU - 91,GMU - 92, GMU - 96,GMU - 99
III	1	GMU - 11
IV	1	Morden
V	1	GMU - 14
VI	1	GMU - 16
VII	1	GMU - 70
VIII	7	GMU - 09,GMU - 23,GMU - 58,GMU - 61,GMU - 66,GMU - 68, GMU - 86
IX	10	GMU - 01,GMU - 24,GMU - 30,GMU - 32,GMU - 43,GMU - 52, GMU - 53,GMU - 60,GMU - 90,GMU - 93
X	1	GMU - 4
XI	1	GMU - 40
XII	1	GMU - 25

Table 2 Average intra and inter cluster distances (D^2 values) of 100 sunflower germplasm accessions along with two checks

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	22.4	28.3	23.9	24.3	24.5	23.9	24.8	27.9	40.5	27.0	42.1	39.4
II		23.1	31.0	29.0	31.5	29.0	27.1	32.7	36.4	41.1	49.8	35.4
III			0	10.2	8.3	22.1	24.4	16.5	50.7	24.7	54.1	35.6
IV				0	10.8	22.3	24.1	16.1	50.2	27.4	55.9	37.5
V					8.5	20.8	24.2	17.7	50.9	25.1	54.1	33.9
VI						0	15.7	20.9	47.1	30.5	49.4	30.1
VII							0	25.3	46.7	35.2	51.7	33.1
VIII								18.7	53.0	29.7	57.3	36.7
IX									26.4	50.0	36.8	52.1
X										0	39.9	49.1
XI											0	63.9
XII												0

Table: 3. Cluster means and per cent contribution of characters towards divergence.

Character/ Cluster	Leaf lamina length (cm)	Leaf lamina width (cm)	Petiole length (cm)	Days to 50% flowering (Days)	Days to Maturity (Days)	Plant height (cm)	Head diameter (cm)	No. Leaves	Per cent seed filling	Oil (%)	Hull (%)	100 seed weight (g)	Seed yield/plant (g)
I	23.1	23.1	15.3	50.0	84.5	131.6	12.5	25.5	43.8	22.3	36.6	5.3	3.4
II	22.2	22.3	13.8	49.9	86.1	135.2	12.3	20.4	61.8	25.8	33.8	5.5	7.7
III	23.0	23.0	12.5	44.0	96.0	144.0	10.8	20.7	8.8	23.6	46.2	3.1	0.9
IV	22.5	22.5	12.0	46.0	81.0	118.2	11.2	21.0	22.7	21.1	33.0	5.7	1.0
V	21.6	21.6	13.8	45.0	81.0	135.2	10.2	20.8	8.3	18.7	50.0	4.0	0.9
VI	21.8	21.8	19.0	48.0	81.0	118.8	17.0	20.2	36.4	20.3	40.0	6.5	1.6
VII	27.5	27.6	16.8	50.0	79.0	135.0	11.2	17.2	76.3	21.5	40.0	4.0	0.4
VIII	23.2	23.3	14.9	50.0	85.7	131.5	12.9	18.6	13.7	22.5	29.9	5.3	1.4
IX	22.2	21.9	15.7	48.7	87.2	130.5	12.2	27.9	70.8	28.0	30.1	4.3	15.2
X	23.0	23.0	17.2	45.0	81.0	133.0	10.4	31.0	13.1	23.1	19.0	5.1	0.9
XI	24.8	24.8	21.0	47.0	79.0	177.0	14.8	39.3	49.2	25.4	34.3	6.5	10.0
XII	9.8	9.8	19.6	44.0	97.0	144.5	13.0	17.2	53.3	25.1	43.3	4.8	5.4
Per cent contribution	1.5	0	1.9	0.3	1.0	0.3	3.5	25.6	4.6	1.4	2.8	17.0	40.2

The data on inter cluster distances and *per se* performance of genotypes were used to select genetically diverse and agronomically superior genotypes. The genotypes, exceptionally good with respect to one or more characters were deemed desirable. On this basis, seven germplasm accessions *viz.*, GMU-25, GMU-40, GMU-4, GMU-70 GMU-16, GMU-14 and GMU-11 were distinct and diverse can be selected as a promising lines. Intercrossing of divergent groups would lead to genetic base in the base population and greater opportunities for crossing over to occur, which intern may release hidden variability by breaking close linkage (Thoday, 1960). The progenies derived from such crosses are expected to show wide variability, providing greater scope for isolating transgressive segregants in the advanced generations. Hence, these genotypes may be used repeatedly in the crossing programmes to recover transgressive segregants, which can be either released as a variety or can be utilized in the genetic enhancement of sunflower crop.

Among the thirteen characters studied, seed yield/plant contributed the most (40.2%) to the genetic divergence of genotypes, followed by number of leaves/plant (25.8%) and hundred seed weight (17.0%). However, days to 50% flowering and plant height contributed the least (0.3%), indicating a narrow range of diversity among the genotypes under study.

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Sowing time and nutrient management vs. sunflower, *Helianthus annuus* L. yield components and yield under irrigated conditions

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Abstract

Field experiments were conducted during 2001 and 2002 in western agro climatic zone of Tamil Nadu to study the effect of sowing times and different nutrient management practices on yield components and yield of sunflower. Among different yield components of sunflower, the head diameter alone showed significant different for sowing taken during 15th Meteorological Standard Week (S_2) during both the year of experiments. The higher seed, oil yields had registered in the same sowing week. With respect to nutrient management practices, during the years, the head diameter, total seeds per head and shelling percentage, the 100% inorganics of recommended dose treatment registered higher values. The same trend was followed in case of seed, oil yield and harvest index also. Hence, the optimum time of sowing for sunflower in western agro climatic zone of Tamil Nadu is during 15th Meteorological Standard week with recommended dose of inorganic source of fertilizers.

Key words: Sunflower yield, sowing time, nutrient management

Introduction

The development of short duration, photo and thermo insensitive high yielding varieties having wider adaptability has revolutionized the cultivation of sunflower (*Helianthus annuus* L.) in different agro climatic regions of India. Conventionally, this crop is grown in Tamil Nadu in different seasons either as rainfed or irrigated under varying soil types and cropping systems. In western agro climatic zone of Tamil Nadu the cultivation of sunflower picked up during late eighties and it has now become an important cash crop in the spring season (January/ February - May) under irrigated conditions. This crop being thermo-insensitive oilseed could be sown throughout the year and can find a place in any cropping system. The sunflower - maize cropping sequence is emerging as important system among the farmers of this region. Sunflower crop is giving additional income to this cropping system. Though the sunflower thermo- insensitive, the cultivars differed in their response to varying seeding dates even in a given season under different agro climatic sub zones (Gaikwad *et.al.*, 1996). Hence, there is a need to adjust the sowing time for this crop in this system, so as to get maximum yield and profit to the farmers.

There is need to promote use of organics in addition to inorganic fertilizers for sustained maintenance of soil fertility (Devidayal and Agarwal, 1999). Owing to the ever-increasing cost of inorganic chemical fertilizers and environmental pollution, there is a need to know the effect on crop with integration of inorganic fertilizers with organic manures.

The present investigation was carried out for identifying optimum sowing time and nutrient management practices for getting higher yield of sunflower.

Materials and methods

The field experiments were conducted during 2001 and 2002 at Tamil Nadu Agricultural University, Coimbatore. The experiments were laid out in Split Plot Design and treatments were replicated thrice. The treatments consisted of three dates of sowing with two weeks interval between each sowing allotted to main plots. First sowing was fixed on 13th Meteorological Standard Week (MSW), (March 26- April 1), second sowing was fixed on 15th MSW (April 9-15) and third was fixed during 17th MSW, (April 23-29). These were five nutrient management practices as presented in table 1. The Farm Yard Manure (FYM) was calculated based on analyzed value for recommended dose of fertilizer for nitrogen alone. This was the only manure applied as per the treatments as organic source. This was given as per the treatments through broadcasting and incorporated into the soil. With respect to inorganic source, the common fertilizers used were urea, single super phosphate (SSP) and Muriate of Potash (MOP) for the supply of nitrogen, phosphorus and potassium respectively. The nutrients recommended for sunflower 40:20:20 Kg N, P_2O_5, K_2O/ha. The total rainfall about 171.6 and 80.1mm were received during 1st and 2nd year of experimentation.

The soil of the experimental field was sandy clay loam type and texturally classified as Typic ustropept. The available nutrient status of the field during the start of the first experiment (*kharif*, 2000) was low in nitrogen (230 kg/ha), medium in phosphorus (18 kg/ha) and high in potassium (430 kg/ha). The organic carbon content was 0.36% with pH 7.55. The sunflower variety CO-2 was used for this experiment with a seed rate of 15 kg/ha and spacing of 30 cm between rows and 30 cm between plants were adopted. The crop has received five irrigations during the crop growth period of each sowing.

Results and discussion

Head diameter of sunflower recorded at different sowings in the years, S_2 sowing was at par with S_1 sowing in the first year, whereas, in the 2nd year, it was significantly superior to all other sowings evaluated. With respect to nutrient management practices, the NM_2 practice registered wider head diameter but it was statistically at par with NM_5 and NM_4 practices in both the years (Table 1). Head diameter is one among the yield components responsible for obtaining higher yield in sunflower. Chidambaram and Sundaresan (1990) reported that there was positive correlation between head diameter and sunflower seed yield.

Total seeds/head in each sowings evaluated did not differ significantly in both the years. Whereas, among nutrient management practices, NM_2 practice recorded an increase of 34% and 33%, respectively, over NM_1 practice in 1st and 2nd year of experimentation and stood superior. In both the years of study, sowings evaluated did not differ significantly in shelling percentage. Among the nutrient management practices studied, the NM_2 practice registered higher shelling percentage and this practice was statistically at par with NM_5 and NM_4 practices.

In both the experiments, neither the sowings nor the nutrient management practices did differ significantly in influencing the hundred seed weight, crude protein and oil content of sunflower.

Seed yield: The sunflower seed yield also was higher under S_2 (15th MSW) sowing. It was observed that the average seed yield registered during 1st year was 1162 kg/ha, while it was 1013 kg/ha during 2nd year (Table 2). During 1st year, S_2 sowing had recorded 1242 kg/ha significantly and the respective increase was 9% and 13% over S_1 and S_3 sowings. Whereas, in the 2nd year, S_2 sowing did produce yield of 1105 kg/ha of sunflower seed. The increase over S_1 sowing was 6%, while it was 19% over S_3 sowing.

Table 1 Effect of sowings and nutrient management practices on yield attributes of sunflower

Treatment	2001						2002					
	Head diameter (cm)	Total seeds/ head	Shelling (%)	100 seed weight (g)	Crude protein (%)	Oil content (%)	Head diameter (cm)	Total seeds/ head	Shelling (%)	100 seed weight (g)	Crude protein (%)	Oil content (%)
Sowings (S)												
S_1	13	479	83	5.8	18.7	36.7	12	468	81.5	5.8	18.4	36.1
S_2	14	496	85	5.9	18.4	37.2	13	486	83.8	5.8	18.1	36.7
S_3	12	458	80	5.8	17.5	37.2	11	449	78.5	5.7	17.2	36.6
SEd	0.3	10.7	1.8	0.12	0.37	0.8	0.3	10.52	1.8	0.12	0.37	0.8
CD (P=0.05)	0.9	NS	NS	NS	NS	NS	0.4	NS	NS	NS	NS	NS
Nutrient management practices (NM)												
NM_1	10	403	74	5.7	18.0	36.8	9.4	398	72.6	5.5	17.8	35.8
NM_2	14	542	87	6.0	18.3	37.3	13.9	530	86.0	5.8	18.1	36.6
NM_3	13	461	82	5.7	18.4	37.0	11.1	445	80.2	5.8	18.2	36.5
NM_4	13	481	83	5.8	18.3	37.3	13.1	473	82.3	5.8	18.1	36.6
NM_5	14	502	86	5.9	17.7	36.8	13.3	493	85.2	5.8	17.4	36.7
SEd	0.4	14.6	2.5	0.2	0.6	1.1	0.4	14.27	2.5	0.2	0.6	1.1
CD (P=0.05)	0.8	30.0	5.3	NS	NS	NS	0.76	29.47	5.2	NS	NS	NS
Interaction												
S x NM												
SEd±	0.68	24.98	4.34	0.31	0.94	1.93	0.65	24.49	4.27	0.30	0.94	1.90
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
NM x S												
SEd±	0.68	25.21	4.41	0.31	0.97	1.98	0.64	24.73	4.34	0.31	0.96	1.95
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS: Not significant

Table 2 Effect of sowings and nutrient management practices on yield attributes of sunflower

Treatment	2001			2002		
	Grain yield (kg/ha)	Harvest index	Oil yield (kg/ha)	Grain yield (kg/ha)	Harvest index	Oil yield (kg/ha)
Sowings (S)						
S_1	1144	23.1	421	1040	22.8	377
S_2	1242	23.7	461	1105	23.5	405
S_3	1101	23.9	410	895	21.7	328
SEd	31.36	0.57	11.77	28.08	0.50	10.35
CD (P=0.05)	67.07	NS	32.70	60.97	1.39	28.73
Nutrient management practices (NM)						
NM_1	694	21.1	255	584	20.3	209
NM_2	1554	2.1	579	1313	24.9	480
NM_3	995	22.3	368	912	21.7	333
NM_4	1220	23.1	455	1094	23.3	401
NM_5	1349	24.0	497	1165	23.0	427
SEd	35.86	0.70	13.23	31.18	0.69	11.38
CD (P=0.05)	74.01	1.44	27.31	64.36	1.41	23.48
Interaction						
S x NM						
SEd±	63.79	0.01	23.64	55.88	0.012	20.44
CD (P=0.05)	NS	NS	NS	NS	NS	NS
NM x S						
SEd±	62.11	0.01	22.92	54.01	0.012	19.71
CD (P=0.05)	NS	NS	NS	NS	NS	NS

NS: Not significant

From the data on nutrient management practices evaluated, NM_2 practice significantly improved the seed yield over all other nutrient management practices in both the years. During 1st year of experiment, the NM_2 practice registered 124% higher seed yield over NM_1 practice while, during 2nd year, the NM_2 recorded 125% over NM_1 practice. Similarly adoption of NM_5 practice also significantly increased seed yield of sunflower as compared to NM_1, NM_3 and NM_4 practices during both the years.

The insight in weather data prevailed during crop growth period indicated that higher evaporation and higher HUE were observed as triggering abiotic factors on the seed yield of sunflower under S_2 sown situation. Since sunflower was sown during summer, evaporation would be more. In the ET studies conducted in the past, even though the component evaporation was started with 40% from seeding, it got declined at the time of highest LAI of the crop and thereupon evaporation was negligible, while the transpiration would be the most important source for water loss. This is in the other word that more ET means more yield. This means that ET is directly proportional to yield obtained. Comparison between rice and pulses yield, the ET requirement of rice was 1200 mm (Reddy, 1999), while it was 300 to 400 mm for pulses (Doorenbos and Pruitt, 1977). Relatively, the yield was higher for rice around five tonnes/ha, while the average yield of pulses was 300 kg/ha. This means that ET is directly proportional to yield obtained. It was reported that the ratio between AET and PET is directly proportional to the ratio between actual and potential yield.

Oil yield: The oil yield of sunflower was significantly influenced by sowings. During 1st year, S_2 sowing registered 461 kg/ha as oil yield and this treatment was significantly superior to other two sowings. Duri j 2nd year, S_2 sowing was (405 kg/ha) at par with S_1 (377 kg/ha) sowing but superior to S_3 sowing. With respect to nutrient management practices studied, the NM_2 practice registered significantly higher oil yield of 127% and 130% over NM_1 in I and II year, respectively. Since, sunflower is grown during summer; the night temperature also would be more. Decrease in minimum temperature was noticed from sowing to 15 DAS, 31 to 60 DAS of both the years of sunflower under S_2 sowing and increase in minimum temperature from 16 to 30 DAS was also observed under the same treatment as compared to other two sowings namely S_1 and S_3. This prevailed minimum temperature during vegetative and flowering stages might have influenced the sunflower seed yield as well as oil yield positively.

The significant increase in seed yield due to inorganic source of nutrients seems to be due to improvement in reproductive (head diameter, total seeds/head) and vegetative growth of the crop as a result of improved source and sink relationship. These results are in close agreement with the findings of Vivek and Chakor (1992)

Harvest Index: From the study, sowings did not differ significantly during 1st year, whereas, in the 2nd year, S_2 sowing significantly improved harvest index than S_3 sowing. In case of nutrient management practices studied, the NM_2 practice registered significantly higher harvest index over other nutrient management practices. Whereas, the NM_5 and NM_4 practices were at par with each other in both the years next to NM_2 practice.

From two years of experiment, it is concluded that optimum time of sowing for sunflower in western agro climatic zone of Tamil Nadu is 15th Meteorological Standard Week. With reference to nutrient management, 100% inorganic source of recommended dose of fertilizer (40:20:20 kg N, P_2O_5, K_2O/ ha) would be the best nutrient management practice for sustainable production of sunflower.

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Combining ability over environments in castor, *Ricinus communis* L.

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Abstract

The combining ability over environments for yield and 10 yield attributes was studied using line x tester mating design involving 5 pistillate lines and 15 inbreds in castor (*Ricinus communis* L.). The estimated components of *gca* and *sca* variances showed preponderance of non additive gene action for most of the characters. The pistillate line SKP 49 was good general combiner for seed yield/plant and yield attributes like, capsules/plant, capsules on main raceme and effective length of main raceme, and for oil content. Among males SPS 43-3, SKI 147 and HC 8 were found good general combiner for yield/plant and other related attributes. The highest *sca* effect was exhibited by SKP 49 x SPS 43-3 for seed yield/ plant as well as capsules/plant. The highest *sca* effect for number of effective branches was recorded by Geeta x DCS-30. The cross combination VP1 x DCS-30 showed highest *sca* effect for number of capsules on main raceme. The parents with high *gca* and crosses with high *sca* effects should be exploited for further breeding programme. The crosses with high *sca* effects for yield/plant and other yield attributing characters should be exploited for heterosis breeding.

Key words: Combining ability, castor

Introduction

Constant efforts to improve yield through selection and hybridization of the parents are important in all crop improvement programmes. Therefore, in any sound breeding programme, the proper choice of parents based on their combining ability is a prerequisite. This also provides necessary information regarding the choice of parents and simultaneously illustrates the nature and magnitude of gene action involved. The estimates of combining ability effect based on single season could not revealed the real merits of the G x E interaction. Hence an investigation was made to assess the nature of combining ability for yield and ten yield attributing characters in four environments through line x tester analysis. The pooled data was used for this study to get reliable information for males, females and crosses.

Materials and methods

The experimental material comprised of 5 pistillate lines (SKP 5, SKP 4, VP 1, Geeta and SKP 49), 15 inbred lines and 75 hybrids among them. The resulting 75 hybrids along with 20 parents were laid out in a RBD with three replications under four environment created by sowing at two different dates (at onset of monsoon and late monsoon) during *kharif*, 1998 and 1999 at Regional Research Station, Gujarat Agricultural University, Sardarkrushinagar. Each plot consisted of 12 plants having an inter and intra row spacing of 90 cm x 60 cm., respectively. Observations were recorded on five randomly selected plants for 11 characters *viz.*, days to 50% flowering (No), days to maturity of main raceme (No), plant height (cm), number of nodes upto main raceme, effective length of main raceme (cm), number of effective branches/plant, number of capsules on main racemes, number of capsules/plant, 100 seed weight (g), oil content (%) and seed yield/plant (g). Mean data were used and analysed according to the method suggested by Kempthorne, (1957).

Results and discussion

The analysis of variance for combining ability in four environments (Table 1) as well as over environments (Table 2) revealed that mean sum of squares due to females and males were significant for all the traits in all the environments except oil content in E_3 for males. The mean sum of squares due to females x males interaction were significant for all the characters in individual environments. This indicated importance of both additive and non-additive gene action in the inheritance of characters studied. Mean sum of squares due to environments, females, males and males x females were significant for all the characters indicating both *gca* as well as *sca* variance to be important in the inheritance of all the characters studied. The interaction sum of squares due to males x environments, females x environments and females x males x environments was found to be significant for all the characters. These findings indicated that both *gca* and *sca* variance were sensitive to environmental fluctuations. These results are in agreement with Dobaria *et al.* (1992), Joshi (1993) and Patel (1994). The magnitude of δ^2 *sca* was higher than δ^2 *gca* for all the characters except plant height and effective branches/plant indicating preponderance of non-additive type of gene action in the inheritance of most of the yield attributes. The results are in agreement with those of *Fatteh et al.* (1988) and Rabadia (1989).

Among the pistillate lines SKP 49 was good general combiner for seed yield/plant, oil content, number of capsules/plant, number of capsules on main raceme, effective length of main raceme, days to 50% flowering and maturity of *main raceme*. Among the inbreds the tester SKI 147 was good general combiner for seed yield per plant. It was also good general combiner for number of *capsules/plant, number of capsules on main raceme*, effective length of main raceme, effective branches/plant, for days to maturity and days to 50% flowering. SPS 43-3 was good general combiner for seed yield/plant and for other yield attributing characters like, number of capsules/plant, number of capsules on *main raceme*, effective length of main raceme, 100 seed weight and oil content. In general HC 8 is better for all traits except maturity time.

Table 1 Analysis of variance sowing mean sum of squares for combining ability in four environments.

Source of variation	d.f.		Days to 50% flowering (No)	*Days to* maturity (No)	Plant height (cm)	No. of nodes upto Main raceme	Effective length of main spike	No. of capsules on main spike	No. of *effective* branches/ plant	No. of capsules/ plant	100 seed weight (g)	Oil content (%)	Seed yield/plant (g)
Females	4	E_1	653.61**	2242.30*	*8914.69***	*135.75***	*1182.48***	4096.31**	76.03**	48568.04*	10.03*	9.89*	*33894.20***
		E_2	3097.24**	14028.25*	2478.11**	18.65**	488.91**	1988.67**	10.72*	25735.44**	10.09*	5.68	14056.69**
		E_3	1332.24**	2398.54*	2729.71**	113.11*	392.52**	2286.67**	58.16**	14066.05**	78.38**	61.98*	10396.82**
		E_4	1472.62**	3121.02*	4003.29**	33.78**	1684.35**	*7897.52***	*98.08**	*1720.98**	123.44**	128.50**	8325.71**
Males	14	E_1	99.02*	295.86*	1167.31**	8.04**	157.58*	499.27*	19.05*	32078.14*	47.65**	7.96*	14058.91**
		E_2	293.34*	714.19*	243.80**	3.50*	62.22*	294.27*	5.84*	1396.51*	41.92**	4.32*	871.26**
		E_3	109.61*	295.54*	754.93**	12.94*	119.80*	217.01*	3.67*	4632.28*	52.28**	10.05	2583.58**
		E_4	291.97*	528.56*	1631.75**	15.09**	688.92**	1514.41**	9.64*	22854.80**	72.31**	32.08**	6439.74**
Females x females	*56*	E_1	104.56*	191.38*	655.76**	2.82*	102.86*	311.22*	11.65*	26839.65*	11.47*	5.32*	7511.59**
		E_2	185.52*	436.92*	167.06**	4.55*	71.62*	160.92*	6.69*	6535.78*	10.47*	3.87*	3871.44**
		E_3	71.44*	218.42*	180.83*	54.71*	96.12*	327.27*	2.47*	4918.03*	9.04*	5.80*	1685.51**
		E_4	234.12*	*236.01**	*447.48**	3.20*	140.09*	605.39*	66.42*	12302.48*	9.49*	15.00*	3831.04**
Error	148	E_1	0.10	0.19	76.38	0.39	16.06	28.16	1.29	178.28	0.09	0.03	220.62
		E_2	0.01	0.19	17.84	0.01	5.28	11.58	0.30	396.93	0.18	0.04	73.54
		E_3	0.30	0.07	16.90	*0.22*	*6.25*	*13.80*	0.14	231.36	*0.08*	*0.01*	*4.64*
		E_4	0.19	0.17	9.77	0.09	1.91	1.46	0.02	54.73	0.01	0.03	15.48

* Significant at P = 0.05
** Significant at P = 0.01

Table 2 Analysis of variance sowing mean sum of squares for combining ability in pooled over environment for different characters in castor.

Source of variation	d.f.	Days to 50% flowering (No)	Days to maturity (No)	Plant height (cm)	No. of nodes upto Main raceme	Effective length of main spike	No. of capsules on main spike	No. of effective branches/ *plant*	No. of capsules/ plant	100 seed weight (g)	Oil content (%)	Seed yield/ plant (g)
Females	4	3073.51*	6526.83**	16336.62**	140.65**	2292.97**	13695.31**	199.01**	57250.07**	73.78**	60.09**	37449.52**
Males	14	448.72*	1077.02**	2271.86**	24.72**	678.55**	1299.99**	17.17**	22516.10**	198.31**	22.98**	9758.66**
Females x Males	56	262.71**	571**	521.81**	6.38**	187.11**	490.32**	7.52*	15322.42*	17.67**	9.22*	6245.60**
Environments	3	2353.56**	30660**	50865.00**	394.19**	44140.56**	50931.05**	493.43**	1143867.00 **	904.96**	1016.70**	279147.70* *
Females x Environments	12	1160.76**	5087.61**	596.49**	20.21**	485.10**	857.95**	14.66**	16109.83*	49.52**	48.64**	9741.13**
Males x Environments	42	115.03*	252.35**	508.62**	*4.96**	116.66**	*408.38**	*7.01**	*12815.36**	*5.62**	*10.48***	4731.56**
Males x *Females x* Environments	168	110.99*	170.30*	309.77**	3.22*	74.53*	304.83*	6.64*	117704.60*	7.60*	0.68*	3544.42**
Error	148	0.15	0.19	30.23	0.17	7.32	13.75	0.44	214.74	0.08	0.03	78.51
δ^2 *sca*		50.57	133.71	70.68	0.05	37.53	61.83	0.29	1183.99	3.36	0.77	900.39
δ^2 *gca*		8.10	6.09	71.16	0.55	8.94	55.66	0.70	182.33	0.82	0.08	113.89
δ^2 *sca* / δ *gca*		6.24	21.04	0.99	0.91	4.20	1.11	0.36	6.50	4.98	9.63	7.91

* Significant at P = 0.05
** Significant at P = 0.01

The specific combining ability effects revealed that a cross SKP 49 x SPS 43-3 had the highest positive significant *sca* effects with respect to seed yield, followed by the crosses VP-1 x 48-1, VP-1 x DSC-30, SKP 49 x SKI 180 and SKP 49 x SH 72. The cross combination SKP 5 x 48-1 for capsules/plant, VP-1 x EC103745 for 100 seed weight, Geeta x DCS-30 for effective branches/plant and VP-1 x DCS-30 for effective length of main raceme. VP-1 x EC 103745, Geeta x EC 103745 and SKP-4 x SKI 119 exhibited highest negative *sca* effect for plant height, days to flowering and maturity, respectively. All the promising hybrids were result of at least one good combining parent with respect to the character with regard to which they had high *sca* effects except VP 1 x 48-1 where both parents are poor combiner for seed yield/plant, but there hybrid is good.

Specific combining ability effects revealed that the crosses SKP 49 x SPS 43-3, Geeta x SKI-147 and SKP-49 x SH-72 showing high *sca* effect for yield per plant involved both good combining parents. Looking to the magnitude of variance due to *sca*, it is obvious that most of the characters under investigation were governed by non-additive type of gene action. Under such a situation the parents with high *gca* effects and the cross combination having highest *sca* effect for yield/plant should be considered for commercial exploitation of heterosis in castor.

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Heterosis over environments for seed yield and other attributes in castor, *Ricinus communis* L.

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Abstract

Heterobeltiosis and standard heterosis for seed yield and its attributes was studied in 75 castor hybrids developed through line x tester mating design (five pistillate lines and 15 pollen parents) under four environments. The significant positive heterosis over better parent (BP) and standard heterosis (SH) for seed yield ranged from 5.57 to 128.46% and 3.58 to 28.98%, respectively. The cross combinations SKP 49 x SPS 43-3, Geeta x SKI 147 and SKP 49 x SH 72 exhibited significant and positive heterosis over check hybrid for seed yield/plant. The superior crosses also exhibited significant and positive heterosis for number of capsules/plant, number of capsules on primary raceme, effective length of primary raceme and oil content. Superior crosses hybrids vigour may be exploited commercially.

Key words: Heterobeltiosis, standard heterosis over environment, castor

Introduction

The exploitation of heterosis has been an important breeding tool in castor, which became feasible due to availability of 100% pistillate lines. Hybrid technology leads to development and release of hybrids at commercial scale in castor. A good number of high yielding hybrids have been released for commercial cultivation. In order to identify high yielding cross combination, it is essential to evaluate available promising hybrid combinations for yield and yield components in varied production environments. Therefore, heterosis over better parent and standard hybrid (GCH-4) was studied in 75 hybrids developed through Line x Tester (5 x 15) mating design under four environments identify superior hybrids over environments.

Materials and methods

Five diverse pistillate lines *viz.*, SKP-5, SKP-4, VP-1, Geeta and SKP-49 and 15 castor inbreds were hybridize in line x tester mating design. The resulting 75 hybrids along with 20 parents (5 lines + 15 testers) were evaluated in randomized block design with three replications in four created environments. Two experiments (one at onset of monsoon and other at late monsoon) during *kharif*, 1998 and 1999 were planted at the Regional Research Station, GAU, Sardarkrushinagar. Each entry was planted in a single row of 12 dibbles keeping row to row 90 cm and 60 cm plant to plant distance. Recommended package of practices was followed for raising the crop. Observations on five randomly selected competitive plants were *recorded in four environments for 11 traits (i.e. days to* 50% flowering of primary raceme, days to maturity, plant height (cm), nodes up to main raceme, effective length of primary raceme, capsules on raceme, number of effective branches/plant, capsules/plant, 100-seed weight, seed yield/plant and oil content). The mean values were used for statistical analysis. The superiority of a hybrid for various traits was observed over the deviation of F_1 from *better parent and standard hybrid (GCH-4), and referred* as heterobeltiosis and standard heterosis respectively as per methods suggested by Fonseca and Patterson (1968). Hybrid technology in castor has been exploited commercially in Gujarat. The hybrid GCH-4 is covering more than 90 per cent of castor area in the Gujarat state. Hence, GCH 4 was used as a standard hybrid (SH) for estimation of economic heterosis.

Results and discussion

Results indicated that mean squares due to parents and hybrids were significant for all the 11 characters studied under four environments indicating considerable genetic variability among parents and hybrids. Mean squares due to parents v/s hybrids were significant for all the traits (except for 100 seed weight in E_1 and E_3 environments) suggesting the presence of hybrid vigour for these traits. Genotype-environmental interaction was also significant for all the traits indicating the presence of considerable amount of genotype x environment interaction. Solanki (2003) also observed importance of genotype x environmental interaction in castor. It was observed that July sowing is more desirable than September sowing during both the year.

The range of mean performance of hybrids was higher than that of parents for seed yield/plant, capsules/plant, capsules on main raceme, effective length of main raceme indicating significant heterosis for these characters.

The range of heterosis, number of significant heterotic crosses and best heterotic crosses over better parent and standard hybrid for 11 traits are presented in Table 1. Earliness in emergence of primary raceme, maturity, and less number of nodes to primary raceme are highly desirable traits for the crop like castor. Hence, the crosses exhibiting heterosis in negative direction are of immense value for identification of early hybrids. Hybrid SKP-49 x HC-8 for days to flowering (-15.48), SKP-4 x SH-72 for maturity of main raceme (-18.28), Geeta x SKI-180 for plant height (-15.57) and for the trait number of nodes, SKP-4 x SKI-80 (-18.67) over better parent, while cross combination VP1 x EC 103745 showed the highest negative heterosis for days to flowering (-5.62), number of nodes up to main raceme (-11.90) and plant height (-32.94). Hybrid SKP 4 x SKI 119 (-6.62) exhibited heterosis in desired direction over standard hybrid for days to maturity of primary raceme.

Table 1 Range of heterosis and number of superior hybrids over environments significant hybrids in desired direction with three best heterotic hybrids over BP and SH for 11 characters in castor

Characters studied	Heterosis over	Range of heterosis		Best heterotic hybrids	No. of hybrids in desired direction
Days to 50% flowering	BP	-0.61	-15.48	SKP49 x HC8	34
	SH	-1.85	-5.62	VP1 x EC103745	3
Days to maturity of primary raceme	BP	-2.16	-18.28	SKP4 x SH72	28
	SH	-1.57	-6.62	SKP4 x SKI119	6
Plant height up to main raceme	BP	-7.46	-15.57	Geeta x SKI180	2
	SH	-13.10	-32.94	VP1 x EC103745	3
Nodes upto primary raceme	BP	-3.25	-18.67	SKP4 x SKI80	11
	SH	-5.43	-11.90	VP1 x EC103745	5
Effective length of primary raceme	BP	5.97	47.25	SKP49 x TMV5	30
	SH	5.72	35.16	SKP5 x SPS 43-3	32
No. of capsules on main spike	BP	10.85	90.16	SKP49 x EC103745	42
	SH	6.83	63.47	SKP5 x SPS 43-3	44
No. of effective branches/plant	BP	8.46	44.39	Geeta x DCS-30	20
	SH	6.12	33.52	Geeta x DCS-30	7
No. of capsules/plant	BP	4.97	110.72	SKP4 x EC103745	59
	SH	4.74	27.33	Geeta x HC8	19
100-seed weight	BP	0.83	22.30	SKP5 x EC103745	14
	SH	0.87	26.85	SKP4 x EC103745	14
Oil content	BP	0.36	7.16	SKP49 x EC103745	38
	SH	0.30	6.67	SKP49 x SKI180	46
Seed yield/plant (g)	*BP*	*5.57*	*128.46*	*SKP49 x EC103745*	*59*
	SH	3.58	28.98	SKP49 x SPS 43-3	14

* BP = Better Parent SH = Standard hybrid (GCH-4)

SKP-49x TMV-5 and SKP 5 x SPS 43-3 showed significant and maximum positive heterosis over BP (47.25%) and SH (36.16%) respectively for length of main spike.

The crosses, SKP-49 x EC 103745 and SKP-5 x SPS 43-3 depicted significant and highest positive heterosis over BP (90.16%) and SH (63.47) respectively for number of capsules on main raceme. Maximum heterosis was observed in hybrid, Geeta x DCS-30 over BP as well as SH for number of effective branches/plant. The SKP-5 x EC 103745 registered maximum heterosis for 100 seed weight (22.30%) over BP. SKP-4 x EC 103745 exhibited significant positive heterosis (110.72%) over BP for number of capsules/plant and over SH (26.85%) for 100 seed weight. Cross Geeta x HC-8 exhibited maximum number of capsules/plant (27.33%) over SH, whereas, SKP-49 x SKI-180 depicted highest heterosis for oil content (6.67%) over SH. The cross, SKP-49 x EC 103745 manifested maximum heterosis for oil content (7.16%) and seed yield/plant (128.46%) over its BP. Similar findings was reported by Patel (1994) and Patel (1997).

Significant positive heterosis for seed yield/plant was ranged from 5.57 to 128.46% and 3.58 to 28.98% over BP and SH respectively. The crosses SKP-49 x EC 103745 and SKP-49 x SPS 43-3 exhibited significant positive heterosis over better parent (128.46%) and SH (28.98%) respectively. Other cross combinations providing higher economic heterosis for seed yield/plant was Geeta x SKI-147 (22.73%) and SKP-49 x SH 72 (12.76%). All these three hybrids also manifested higher seed yield/plant. These crosses are likely to give better transgressive segregants and could be used for further improvement work.

The magnitude of heterosis over BP and SH varied from cross to cross for seed yield and its components. This indicated that all the characters distinctly differed for mean heterosis and its range in desirable direction. Considerable high heterosis in certain crosses and low in others revealed that nature of gene action varied with the genetic make up of the parents involved in crosses. As such, nature and magnitude of heterosis helps in identifying superior cross combinations to obtain better transgressive segregants.

Comparison of top five crosses for yield per se, heterosis over BP and SH (SKP 49 x SPS 43-3, Geeta x SKI 147, SKP 49 x SH 12, SKP 49 x SKI 180 and Geeta x HC 8) (Table 2) indicated that they are accompanied by significant and positive heterosis over BP and SH for yield attributes like number of capsules/plant, effective length of raceme, number of capsules on main raceme, earliness and oil content, indicating the heterosis for seed yield was manifested through the yield component characters.

The present study suggested that heterosis for seed yield should be through component trait heterosis. Hybrid vigour even in small magnitude for individual yield components may have additive or synergistic effect on the end product. Thus, additive gene action of these characters ultimately resulted in high yield heterosis. Graffius (1959) also reported that the yield is the end product of multivariable interaction between yields components. Similar findings were also reported in castor by Patel (1994), Patel (1997) and Solanki and Joshi (2000). Thus, on the basis of *per se* performance and heterotic response, the crosses SKP 49 x SPS 43-3, Geeta x SKI 147 and SKP 49 x SH 72 were indicated as suitable for exploitation of heterosis for seed yield in castor.

Table 2 Heterobeltiosis and standard heterosis of superior crosses for seed yield and other components in castor

Crosses	Mean seed yield / plant		Days to 50% flowering	Days to maturity of primary raceme	Plant height	No. of nodes upto primary raceme	Length of primary raceme	No. of capsules on main raceme	No. of effective branch per plant	No. of capsules/ plant	100 seed weight	Oil content (%)	Seed yield / plant
SKP 49 x SPS 43-3	261.62	BP	-5.13**	-11.19**	89.89**	-1.61	25.06**	30.77**	-4.27	37.23**	-4.20**	0.44**	42.63**
		SH	20.43**	12.13**	42.29**	13.84**	30.48**	35.98**	-13.25**	25.47**	20.81**	1.12**	28.98**
Geeta x SKI 147	248.95	BP	-7.43**	-3.55**	1.14	5.97**	6.59*	-1.28	8.46**	33.76**	-1.43**	0.54**	41.85**
		SH	22.90**	16.05**	31.86**	16.74**	4.39	4.41	6.46*	14.93**	3.57**	0.30*	22.73**
SKP 49 x SH 72	228.72	BP	-14.36**	-17.33**	62.14**	1.54	21.72**	12.51**	25.00**	52.72**	-2.54**	1.64**	47.27**
		SH	11.28**	4.36**	21.51**	5.95**	12.98**	22.67**	-16.99**	13.78**	9.22**	2.10**	12.76**
SKP 49 x SKI 180	224.97	BP	-11.74**	-5.25**	76.76**	0.64	17.58**	0.88	26.28**	47.71**	-5.67**	2.42**	37.08**
		SH	24.49**	19.61**	32.45**	16.44**	33.40**	52.28**	-16.08**	12.78**	-0.58	6.67**	10.91**
Geeta x HC 8	224.22	BP	9.42**	3.62**	-7.46**	-8.44	-3.47	-2.81	23.27**	64.98**	-3.07**	-1.74**	52.20**
		SH	45.26**	24.68**	50.98**	20.39**	17.19**	-3.73	14.04**	27.33**	14.47**	2.92**	10.54
S.Em. ±			0.16	0.19	12.23	0.19	1.13	1.59	0.25	5.95	0.12	0.07	3.45

* Significant at P = 0.05; ** Significant at P = 0.01

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Effect of tillage and soil moisture regimes on seedling emergence, growth and yield of summer castor, *Ricinus communis* L. in rice fallows

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Abstract

Field experiments were conducted during summer seasons of 1996-97 and 1997-98 on sandy clay loam soil after rainy season puddle rice at Agricultural College Farm, Rajendranagar, Hyderabad. Four tillage practices constituting ploughing with bullocks or tilling with tractor with rotovation or harrowing besides no secondary, tillage and three soil moisture regimes constituting scheduling of irrigations at IW/CPE ratio = 0.6, 0.4 and 0.2 were evaluated. Significantly higher seedling emergence, growth and yield were observed when secondary tillage was carried out with power tiller rotovator following ploughing either with country plough or tractor tiller (cultivator). Higher castor seed yield was obtained at soil moisture regime of IW/CPE = 0.6 or 0.4 compared to 0.2 ratio. Highest net returns and B: C ratio were obtained in ploughing twice with country plough followed by rotovation twice with power tiller. Further, scheduling irrigation at 0.6 or 0.4 IW/CPE ratios resulted' in higher net monetary returns and B: C ratio compared to 0.2 ratio.

Key words: Tillage, soil moisture regime, castor, rice fallow

Introduction

Under situations of limited water availability for growing rice as second crop there is possibility of growing castor in rice fallow situation of command areas of various irrigation projects of Andhra Pradesh. Soil conditions after puddle rice pose limitations for growing upland crops and thus the yield levels of crops following rice are generally low as compared to normal yields (Reddy and Reddy, 1979). Loosening puddle soil may require special tillage. Large tractors with attachments that pulverize hard soil are now available, but they are too expensive for small farmers. Inexpensive and effective tillage practices to eliminate drudgery and ensure proper seed bed preparation are badly needed (Prihar *et al*., 1985). Keeping in view the above, field experiments were conducted for two years to study the effect of tillage and soil water regimes on productivity of summer castor in rice fallows.

Material and methods

The experimental site was located at Agricultural College Farm of ANGRAU, Rajendranagar, Hyderabad (17°19' E, 78°28' N, 535 m above mean sea level, annual rainfall of760 mm). The soil was sandy clay loam; composition of top soil (0-15 cm) was sand 60.2%, silt 13.8% and clay 26.0%. The depth of soil was medium (50-60 cm). The pH and EC (dS/m) of the soil were 8.0 and 0.13 respectively, in 1:2 soil: water suspension. The available water holding capacity of the soil profile of 45 cm depth was 7.9 cm.

The experiment was laid out in Strip Plot Design (four main tillage treatments and three soil moisture regimes) replicated thrice. Castor hybrid 'GCH 4' was the test crop. The seed rate, fertilizer dose, plant protection measures, harvesting and threshing of crop was similar for all treatments. The crop was raised with the recommended package of practices for the region.

The mean weekly pan evaporation ranged from 2.1 to 10.1 mm/day (average 6.10) and 3.2 to 10.9 (average 7.05) during crop growth period of 1996-97 and 1997-98, respectively. A total rainfall of 29.2 and 12.0 mm in 12 and 4 rainy days was received during 1996-97 and 1997-98, respectively during the crop growing season. The mean weekly maximum and minimum temperatures during the cropping period ranged from 26.30C to 41.2°C and 10.8°C to 26.2°C; and 28.5°C to 42.3°C and 12°C to 28.6°C during 1996-97 and 1997-98, respectively. The mean relative humidity ranged from 29.3 to 64.6 and 38.9 to 69.5% during crop growth periods of first and second years, respectively. The weekly bright sunshine hours varied from 6.6 to 11.0 during 1996-97 and 7.3 to 10.9 during 1997-98.

The IW/CPE ratio of 0.6, 0.4 and 0.2 received 7, 5 and 3 irrigations during 1996-97 with total amount of irrigation water of 350, 250 and 150 mm respectively and during 1997-98, the same treatments were provided 11, 8 and 4 irrigations with total quantity of 550, 400 and 160 mm irrigation water, respectively. To minimize the interference of water from one treatment to another a 50 cm wide drain and successive 50 cm levee were constructed in between different plots. Irrigation water was applied according to the treatments and was measured by water meter.

The clod size distribution was determined and expressed in terms of mean weight diameter (MWD) calculated in accordance with the procedure suggested by Youker and Mc Gunnis (1957). Seedling emergence was determined by counting number of seed hills emerged from each test plot. Growth was expressed in terms of dry matter (above ground parts) at harvest. The spikes in each net plot were picked thrice and threshed separately. Clean bean yield at 9% moisture was recorded from each test plot. The experimental data were subjected to Fisher's method of Analysis of Variance (ANOVA) as per Panse and Sukhatme (1978).

Results and discussion

Seedbed Quality: Tillage with high drought machinery like tractor (T_3 and T_4) tilled the soil to deeper depth of 21 cm, while tillage with bullock drawn country plough tilled to 12 cm depth (Table 1). Working power tiller drawn rotovator twice following ploughing twice with country plough (T_2) and tractor tilling twice with cultivator (T_3) contained higher percentage of smaller clods and lower percentage of larger ones. It also revealed that different tillage treatments especially secondary tillage implements could induce considerable differences in MWD of clods. The MWD of clods was higher in case of secondary tillage with tractor tiller and disc harrow and lower under power tiller drawn rotovator irrespective of primary tillage. The higher percentage of smaller clods in these treatments involving rotovation might be attributed to churning of soil by power tiller rotovator (Rao and Prasadini, 1994).

Seedling emergence: The percentage of emergence of seedlings was significantly higher in plots tilled with rotovator following ploughing either with bullock drawn country plough and tractor drawn tiller (cultivator) which was significantly higher than harrowing following tractor tiller (cultivator) tilled treatments (Table 1). Lowest seedling emergence (72%) was observed in the treatment of ploughing twice with country plough alone. Soil water regimes had no effect on seedling emergence. Finer soil tilth provided by higher percentage of smaller clods and lower MWD of clods resulting from rotovation might have also offered less resistance to seedling emergence and provided a chance for even weaker seedlings to emerge due to reduction in imp edition at seed - soil - water contact, thereby increasing the moisture availability to seeds and ultimately improved the seedling emergence (Pratibha *et al.*, 1994; Rao and Prasadini,1994).

Growth parameters

Drymatter accumulation: Favourable soil conditions created under rotovation treatments (T_2 and T_3) supported the crop with higher relative leaf water content, thus resulting in higher dry matter accumulation (Table 2). Further, fine tilth obtained with rotovation and deep ploughing with tractor drawn implements might have increased the uptake of nutrients and water from greater volumes of soil resulting in higher dry matter accumulation (Kumar *et al.*, 1999). Increase in soil moisture regime upto 0.4 IW/CPE significantly increased the dry matter accumulation at harvest. This could be attributed to lower soil moisture stress prevailing before next irrigation in the plots irrigated with IW/CPE ratio of 0.4 and 0.6 (Rao, 1983). On the other hand in IW /CPE ratio of 0.2 irrigation regime, plants experienced relatively higher soil moisture stress thereby lower dry matter accumulation. Decrease in dry matter accumulation due to moisture stress in castor was also reported by Selvaraj *et al.* (1992). The interaction effects of tillage and soil moisture regime did not affect significantly the dry matter production.

Yield attributes: Yield attributes *viz.*, number of capsules per plant and length of primary spike were significantly higher in plots tilled with power tiller rotovator following either ploughing twice with country plough and tractor tilling twice with cultivator; which was significantly higher than other treatments (Table 2). Increase in yield attributing characters under rotovation treatment was also reported by Pratibha *et al.* (1994). Irrigation given at shorter intervals by adopting relatively higher soil moisture regimes (IW/CPE ratio = 0.4 and 0.6) resulted in better yield attributes compared to those scheduled at longer interval (IW/CPE = 0.2). These results are in accordance with Rao (1983).

Seed yield: Significantly higher seed yield (Table 3) was registered with tractor tilling followed by rotovation twice and ploughing twice with country plough followed by working twice with power tiller rotovator compared to other treatments due to congenial physical edaphic conditions. Tillage treatment involving rotovation resulted in soil churning which might have resulted in increase in seedling emergence due to better seed - soil - water contact, better plant stand, higher dry matter production and yield attributes and ultimately reflected in higher seed yield of castor in rice fallows (Pratibha *et al.*, 1994). Further the water use efficiency of the crop increased due to rotovation (Table 3). Providing 50 mm irrigation water at IW/CPE ratio of 0.4 registered highest seed yield, which was on par with IW/CPE ratio of 0.6 and both were significantly superior to 0.2 ratio (Rao *et al.*, 1983). However, increase in IW/CPE ratios from 0.2 to 0.4 and 0.6 decreased the water use efficiency of castor in rice fallows (Table 3).

Table 1 Effect of tillage treatments on clod size distribution, mean weight diameter (MWD), depth of ploughing (cm) and seedling emergence of castor in rice fallows

Tillage treatment	Clod size (mm-diameter) per cent							MWD (mm)	Mean depth of ploughing (cm)	Seedling emergence (%)
	>100	50-100	20-50	10-20	5-10	2-5	<2			
1996-97										
T_1	16.4	20.2	18.2	14.4	11.5	9.2	10.1	31.6	10.6	73
T_2	4.4	12.0	17.2	18.8	17.4	14.1	16.1	20.4	12.2	85
T_3	11.4	20.2	21.6	15.0	9.2	8.4	14.2	26.8	20.6	83
T_4	12.4	16.9	19.8	17.2	9.2	11.9	12.6	29.2	21.8	78
CD (P=0.05)	6.2	3.6	0.8	2.4	5.5	3.9	1.8	2.5	5.8	0.9
1997-98										
T_1	15.6	21.4	19.8	13.2	10.5	8.7	8.8	32.3	10.2	71
T_2	2.6	12.5	15.6	16.4	17.8	14.3	20.8	21.2	12.8	86
T_3	12.2	19.1	20.4	13.3	8.9	9.2	16.9	23.6	21.2	82
T_4	12.9	14.9	16.7	17.6	13.0	12.6	12.3	30.2	21.4	78
CD (P=0.05)	7.3	3.0	2.2	2.4	2.8	3.0	3.8	2.8	4.2	0.7

T_1 : Ploughing twice with country plough alone
T_2 : Ploughing twice with country plough followed by working twice with power tiller rotovator
T_3 : Tractor tilling twice with cultivator followed by rotovating twice with power tiller rotovator
T_4 : Tractor tilling twice with cultivator followed by harrowing twice with offset disc harrow

Table 2 Effect of tillage treatments and soil moisture regimes on growth and yield attributes of summer castor in rice fallows

Treatment	Drymatter at harvest (kg/ha)			No. of capsules/plant			Length of primary spike (cm)		
	1996-97	1997-98	Pooled mean	1996-97	1997-98	Pooled mean	1996-97	1997-98	Pooled mean
Tillage (T)									
T_1	3682	3564	3623	88	90	89	25	27	26
T_2	4621	4476	4549	102	101	102	31	32	32
T_3	4678	4498	4588	102	103	103	32	32	32
T_4	4363	4119	4241	97	95	96	29	29	29
CD (P=0.05)	38	57	44	8	4	7	2.2	2.4	
Soil moisture regime*(I)									31
I_1	4526	4359	4443	100	99	100	30	32	32
I_2	4545	4411	4478	106	103	105	32	32	26
I_3	3939	3724	3830	86	91	89	26	26	3.0
CD (P=0.05)	22	26	16	11	6	10	2.9	3.2	

T_1 : Ploughing twice with country plough alone
T_2 : Ploughing twice with country plough followed by working twice with power tiller rotovator
T_3 : Tractor tilling twice with cultivator followed by rotovating twice with power tiller rotovator
T_4 . Tractor tilling twice with cultivator followed by harrowing twice with offset disc harrow
I_1 : IW/CPE ratio of 0.6
I_2 : IW/CPE ratio of 0.4
I_3 : IW/CPE ratio of 0.2
*Depth of water applied at each irrigation = 50 mm

Table 3 Effect of tillage treatments and soil moisture regimes on yield, water use efficiency and economics of summer castor in rice fallows

Treatment	Seed yield (kg/ha)			Water use efficiency (kg/ha - mm)			Net returns (Rs/ha)			Benefit : Cost ratio		
	1996-97	1997-98	Pooled mean	1996-97	1997-98	Pooled mean				1996-97	1997-98	Pooled mean
Tillage (T)												
T_1	1150	1444	1297	5.1	4.8	5.0	-50	3645	1298	1.00	1.27	1.14
T_2	1757	1983	1870	7.5	6.6	7.1	7054	9933	8494	1.50	1.72	1.61
T_3	1746	1999	1873	7.5	5.9	6.7	6742	9945	8344	1.48	1.71	1.60
T_4	1634	1677	1656	6.8	5.6	6.2	5218	5901	5560	1.36	1.41	1.39
CD (P=0.05)	97	141	202	-	-	-	-	-	-	-	-	-
Soil moisture regime*(I)												
I_1	1802	1917	1860	4.8	3.5	4.2	7171	8851	8011	1.50	1.63	1.57
I_2	1818	1964	1891	7.3	4.6	6.0	7740	9415	8578	1.55	1.69	1.62
I_3	1225	1447	1336	8.2	9.0	8.6	747	3611	2179	1.05	1.26	1.16
CD (P=0.05)	312	251	206	-	-	-	-	-	-	-	-	-

T_1 : Ploughing twice with country plough alone
T_2 : Ploughing twice with country plough followed by working twice with power tiller rotovator
T_3 : *Tractor tilling twice with cultivator followed by rotovating twice with power tiller rotovator*
T_4 : Tractor tilling twice with cultivator followed by harrowing twice with offset disc harrow
I_1 : IW/CPE ratio of 0.6
I_2 : IW/CPE ratio of 0.4
I_3 : IW/CPE ratio of 0.2
*Depth of water applied at each irrigation = 50 mm

Economics: In general tillage practices involving rotovation (T_2 and T_3) have shown their superiority over reduced tillage (T_1) under rice fallows regarding net monetary returns and Benefit: Cost ratio (Table 3). Scheduling irrigations at IW/CPE ratios of 0.4 and 0.6 resulted in higher net returns and B: C ratio of Rs.8578/ha and Rs.8011/ha and 1.62 and 1.57 over two years, respectively. Thus deep and fine tillage under rotovation treatments resulted in highest net returns and B: C ratio as stated by Vittal *et al.* (1983) and Gurumurthy and Singa Rao (2003).

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Effect of mechanical control of defoliators in the pest management of castor, *Ricinus communis* L.

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Abstract

Castor, *Ricinus communis* L. crop is attacked by a number of insect pests, particularly the defoliators, sucking pests and capsule borer. Investigations were carried out to study the impact of mechanical control of defoliators as a component in the pest management of castor. The insecticides *viz.*, fenvalerate 0.02%, monocrotophos 0.05% and endosulfan 0.07% were effective in controlling semilooper. However, these insecticides significantly lowered the parasitisation of semilooper by *Microplitis*, a potent field parasitoid. The insecticides could not reduce the infestation of *Spodoptera* and *Spilosoma* resulting in higher defoliation. Control of defoliators by mechanical control could reasonably reduce semilooper and effectively lowered infestation of *Spodoptera* and *Spilosoma* which ultimately resulted in low defoliation levels. Among insecticide treatments, monocrotophos 0.05% was effective against leafhopper and thrips, while fenvalerate 0.02% flared up the populations of the sucking pests. NSKE 5% was less effective against defoliators and sucking pests. Erection of bird perches could not reduce the infestation of defoliators. The subsequent damage due to capsule borer was high in the treatments where insecticides were used for the control of defoliators, while the damage was low in the treatments where mechanical control of defoliators was practised. Higher seed yield was obtained in mechanical control and monocrotophos 0.05% treatments alone and in combination.

Key words: Castor, insect defoliators, sucking pests, capsule borer, mechanical control, insecticides, bird perches

Introduction

Castor (*Ricinus communis* L.) is infested with a number of insect pests at different phenological stages of the crop in India (Rai, 1976). The important pests include semilooper (*Achaea janata* L.), tobacco caterpillar (*Spodoptera litura* Fabr.) and Bihar hairy caterpillar (*Spilosoma obliqua* Wlk.), among defoliators, the leaf hopper (*Empoasca flavescens* Fabr.) and thrips (*Retithrips syriacus* Mayet.), among sucking pests and the capsule borer [*Conogethes (Dichocrocis) punctiferalis* Guen.] (Lakshminarayana and Raoof, 2005). Control of these pests with insecticides like fenvalerate, monocrtophos and endosulfan is commonly recommended (Anonymous, 2002). Use of pesticides may at time becomes difficult for the farmers of rainfed farming and also often pesticides do not bring satisfactory control of certain pests like capsule borer. Castor is also reported to tolerate higher defoliation without considerable yield loss (Kittock and Williams, 1967). The present investigations were carried out to study the impact of mechanical control in managing defoliators and its effect on the activity of parasitoids and subsequently the capsule borer infestation and the seed yield.

Materials and methods

Different large plot field experiments were conducted at farmers' fields and Research Farm of the Directorate of Oilseeds Research, Rajendranagar, Hyderabad using castor variety, DCS-9.

Studies on mechanical control of defoliators at farmers' fields: The investigations were carried out with five treatments in the farmers' fields at Bowinapally village, Nalgonda district of Andhra Pradesh during 1996 in collaboration with voluntary organisations. Each treatment was imposed in an area of 2 hectares. In complete mechanical control treatment, the older larvae of semilooper and gregarious stages of *Spodoptera* and *Spilosoma* were hand picked and destroyed at weekly interval during the pest infestation (August-October). In partial mechanical control, farmers attempted mechanical control once or twice initially and later resorted to other methods of pest control. Endosulfan 0.07% sprays in different treatments were given at 15 days interval (Table 1).

Studies on effect of mechanical control *vis-a-vis* chemical control in managing castor pests: Experiment was conducted with five treatments (Table 2) each in a field plot of 0.2 ha during *kharif*, 1997 at Research Farm (Narkhoda) of the Directorate of Oilseeds Research. The insecticides were sprayed twice for the control of defoliators at 20 days interval. The mechanical control of defoliators was practised at weekly interval.

Studies on integrated management of defoliators: Experiment was conducted at the Research Farm (Narkhoda) of the Directorate during 2000 and 2001 with six treatments (Table 3), each imposed in large field plot of 1200-2800 sq.m. The bird perches were erected at a height of 150-180 cm from ground level. Mechanical control of defoliators was carried out at weekly interval, while monocrotophos 0.05% spray was given twice at 15 days interval.

The observations were recorded on 10 plants in each treatment in all the experiments on the infestations of different defoliators, corresponding defoliation, larval parasitisation of semilooper by *Microplitis*, 10 days after imposing the treatments. The subsequent infestations of sucking pests and capsule borer were also recorded in each treatment. The mean infestations of different pests were calculated for each treatment and presented along with yield data.

Results and discussion

Studies on mechanical control of defoliators at farmers' fields

The major defoliators observed during the study were semilooper, *Spodoptera* and *Spilosoma*. The maximum pest populations observed after imposing different treatments are presented in table 1. The treatments with endosulfan 0.07% sprayed twice or thrice were effective in reducing the semilooper (0.3-0.4 larvae/plant). Ahuja *et al.* (1998) also reported endosulfan to be effective against semilooper. Though complete mechanical control treatment could reduce semilooper significantly compared to untreated control, it was less effective over the treatments involving insecticide applications. But, the treatments where insecticide was a component, showed lower larval parasitisation by *Microplitis maculipennis* recording 48.5 to 56.3% compared to 74.2% in complete mechanical control.

The infestations of *Spodoptera* (2.1/plant) and *Spilosoma* (0.8/plant) were low in the treatment where they were removed only by mechanical control. Partial mechanical control of defoliators combined with endosulfan 0.07% could not reduce these defoliators. High populations of these pests in endosulfan 0.07% treatment compared to untreated control suggested that more applications of insecticide was not only ineffective, but also flared up the infestations of *Spodoptera* and *Spilosoma*. Dhingra and Dhingra (1998) reported high susceptibility of semilooper and low susceptibility of *Spodoptera* and *Spilosoma* to many insecticides based on LC_{50} values.

The lowest defoliation (9.8%) was recorded in complete mechanical control treatment. The defoliation was significantly high (28.5 to 35.3%) in different treatments involving endosulfan 0.07% application. A maximum of 45.5% defoliation was resulted in untreated control.

Low capsule borer damage (8.5%) was observed subsequently in the complete mechanical control and untreated control (7.8%), while the borer infestation was high (11.4 to 13.6%) in the fields received the insecticide for the control of defoliators.

Significantly higher yield (958 kg/ha) was recorded in the fields where defoliators were controlled mechanically. This was due to low populations of defoliators and low capsule borer infestation later. The differences in the yield obtained from other treatments and untreated control were not significant.

Studies on mechanical control *vis-a-vis* chemical control of defoliators

The maximum infestations of various pests after imposing different treatments are presented in table 2 along with yield data.

The treatments *viz.*, fenvalerate 0.02% and monocrotophos 0.05% were effective against semilooper recording 0.13 and 0.30 larvae/plant, respectively, while, NSKE 5% was less effective. Ahuja *et al.* (1998) reported fenvalerate and monocrotophos to be effective against semiloooper, while, use of fenvalerate followed by azadirachtin spray was found to be superior in the reduction of the pest according to Basappa and Lingappa (2004). The semilooper population was significantly reduced (2.8/plant) with mechanical control compared to untreated control (5.4/plant). The semilooper parasitisation was affected adversely with these insecticides, more so with fenvalerate 0.02%, whereas, Basappa and Lingappa (2004) observed only a moderate toxic effect of fenvalerate on the natural enemy. NSKE 5% was less harmful to the larval parasitoid, showing 61.5% parasitisation whereas, highest parasitisation (78.7%) was recorded in mechanical control treatment.

Among different insecticide treatments, fenvalerate 0.02% was superior in controlling *Spodoptera* (4.2 larvae/plant), but recorded lowest *Apanteles* activity (0.9/plant). Monocrotophos 0.05% and NSKE 5% treatment could not effectively reduce the pest, while, NSKE was found to be useful in managing castor defoliators by Saroj Singh *et al.* (2005). Singh and Kanujia (2003) reported NSKE to be less effective against *Spilosoma*. Lowest *Spodoptera* infestation (3.4/plant) and high *Apanteles* population (3.2/plant) was observed in mechanical control treatment.

Lowest defoliation (9.4%) was observed in mechanical control as against 41.4% in untreated control. The defoliation levels ranged from 12.6 to 26.8% in different insecticidal treatments.

High infestations of leafhopper (35.5/3 leaves/plant) and thrips (14.2/leaf) were noticed in fenvalerate 0.02% treatment, whereas monocrotophos 0.05% was the most effective against these sucking pests. The population of leafhopper (16.8/3 leaves/plant) was also high in NSKE

5% compared to that in mechanical control (12.1) and untreated control (11.2) treatments. Paramar *et al.* (2004) reported azadirachtin to be less effective against leafhopper.

The capsule borer infestation was high (28.4%) in fenvalerate 0.02% followed by monocrotophos 0.05% (23.7%). Low incidence of the borer (11.6-12.9%) was recorded in NSKE 5% and mechanical control treatments.

Highest seed yield (876 kg/ha) was recorded in mechanical control treatment. However, the differences in yield among mechanical control and other treatments where insecticide was a component were non-significant.

IPM of defoliators

The populations of defoliators, levels of defoliation and capsule borer infestation in different treatments involving mechanical control, bird perches and monocrotophos 0.05% are presented in table 3.

Table 1 Mechanical control of defoliators in castor at farmers' fields

Treatment	Defoliators (larvae/plant)			Semilooper parasitisation by *Microplitis* (%)	% defoliation	% capsules damaged by capsule borer	Yield (kg/ha)
	Semilooper	*Spodoptera*	*Spilosoma*				
Complete mechanical control	1.8	2.1	0.8	74.2 (59.5)	9.8 (18.2)	8.5 (16.9)	958
Partial mechanical control + endosulfan 0.07% sprays (2)	0.4	5.2	3.6	56.3 (48.5)	28.5 (31.9)	11.8 (20.1)	807
Endosulfan 0.07% sprays (3)	0.3	7.8	5.0	48.5 (43.9)	35.3 (36.2)	13.6 (21.5)	800
Partial mechanical control + release of *Trichogramma* @ 80,000/ac + endosulfan 0.07% spray	1.3	5.1	3.1	54.6 (47.3)	30.4 (33.3)	11.4 (19.6)	815
Untreated control	4.6	4.8	3.7	68.4 (55.7)	45.5 (42.1)	7.8 (16.1)	785
SEm±	0.2	0.4	0.5	1.5	1.4	1.0	22.5
CD (P=0.05)	0.7	1.0	1.5	4.7	4.3	3.2	69.2

Figures in parentheses are angular transformed values

Table 2 Effect of mechanical and chemical control on the major pests in castor

Treatment	*Semilooper*/ plant	Semilooper parasitisation by *Microplitis* (%)	*Spodoptera*/ plant	*Apanteles*/ plant	% defoliation	Leaf hopper/ 3 leaves/ plant	Thrips/ leaf	% capsules damaged by capsule borer	Yield (kg/ha)
Fenvalerate 0.02%	0.1	34.0 (35.6)	4.2	0.9	12.6 (20.6)	35.5	14.2	28.4 (32.2)	778
Monocrotophos 0.05%	0.3	48.2 (43.9)	6.2	2.1	15.7 (23.2)	6.1	2.6	23.7 (29.1)	814
NSKE 5%	3.7	61.5 (51.7)	7.1	1.8	26.8 (30.9)	16.8	7.9	12.9 (21.1)	794
Mechanical control	2.8	78.7 (62.6)	3.4	3.2	9.4 (17.5)	12.1	5.3	11.6 (19.9)	876
Untreated control	5.4	69.1 (56.2)	8.5	3.6	41.4 (40.0)	11.2	6.1	9.8 (18.2)	761
SEm±	0.23	1.1	0.3	0.1	2.41	1.34	0.82	1.7	27.2
CD (P=0.05)	0.72	3.3	0.9	0.5	7.44	4.13	2.52	3.6	83.9

Figures in parentheses are angular transformed values.

Table 3 IPM of defoliators in castor

Treatment	Semilooper/plant		% semilooper parasitisation by *Microplitis* (mean)	*Spodoptera*/plant		*Apanteles*/ plant (mean)	Mean % defoliation	% capsule borer damage (mean)	Yield (kg/ha)	
	2000	2001		2000	2001				2000	2001
Bird perches @ 50/ha	4.2	4.7	62.5	5.6	6.2	4.2	45.5	11.4	756	896
Mechanical control	1.9	1.6	77.3	2.9	1.8	3.9	15.7	12.8	1024	1028
Monocrotophos 0.05%	0.4	0.3	41.8	4.4	3.7	1.4	16.4	18.6	948	1094
Bird perches + Mechanical control	1.7	2.1	71.9	1.9	2.2	4.1	12.6	11.8	1006	[illegible]
Bird perches + Mechanical control + Monocrotophos 0.05%	0.7	0.3	46.4	1.4	1.2	2.6	8.7	14.3	985	1116
Untreated control	4.8	4.1	65.1	6.7	5.8	3.8	42.8	12.1	788	871
SEm±	0.3	0.3		0.5	0.4				28.5	31.2
CD (P=0.05)	1.1	0.8		1.4	1.2				91.9	97.6

The infestations of semilooper (4.2-4.7/plant) and *Spodoptera* (5.6-6.2/plant) were not reduced with the erection of bird perches. Similar semilooper infestations were found in untreated control both in 2000 and 2001. Mechanical control could reduce semilooper (1.6-1.9/plant) compared to untreated control (4.1-4.8), while, the treatments involving monocrotophos 0.05% effectively reduced the semilooper (0.3-0.7). Lower semilooper parasitisation by *Microplitis* was recorded in the treatments involving monocrotophos 0.05% (41.8-46.4%), while the levels were high (62.5-77.3%) in the other treatments.

Lowest population of *Spodoptera* (1.2-2.9/plant) was observed in the plots where mechanical control was implemented alone or in combination with bird perches and monocrotophos. Monocrotophos 0.05% alone was less effective (3.7-4.4/plant) against *Spodoptera* suggesting that mechanical control is more effective than the insecticide in controlling the pest. Low population of *Apanteles* (1.4-2.6/plant) was observed in the treatments with monocrotophos, while the parasitoid activity was high (3.8-4.2) in the remaining treatments.

As the bird perches were ineffective in reducing the defoliators, a defoliation of 45.5% was recorded, which was similar to that in untreated control (42.8%). But, Saroj Singh *et al.* (2005) reported that bird perches were useful in managing the defoliators and they alone reported to reduce semilooper population by 50% (Prabhakar *et al.*, 2003). The level of defoliation was 8.7-16.4% in the remaining treatments.

More capsule borer damage (14.3-18.6%) was noticed in the treatments where monocrotophos 0.05% was used for the control of defoliators, unlike low borer infestation (11.4-12.8%) in the rest of the treatments.

The yield (756-896 kg/ha) obtained from the treatment where bird perches alone were used was not significant from the yield recorded in untreated control in both the years. Significantly higher yields were recorded in mechanical control and monocrotophos (0.05%) treatments alone and in combination (948-1116 kg/ha) though differences were not significant within these treatments.

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Seed yield stability in niger, *Guizotia abyssinica* Cass.

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Abstract

Ten elite genotypes with three check varieties of niger were evaluated for their seed yield performance using seven different stability parameters over five years. Out of five seasons, three were favourable and two were unfavourable for crop performance. The sum of squares due to genotypes and environment were significant, indicating presence of substantial genetic variability among the genotypes and season. The G x E interaction was found significant. On partition of the same into linear and non-linear components both were significant, suggesting their importance in the expression of seed yield in niger. However, the linear component was larger in magnitude indicating the prediction of performance across the environment is possible. On examination of individual stability parameters, the genotypes IGPN-9606, IGPN-9614 and IGP-76 were observed to be stable. Simultaneously the genotypes IGPN-9602, IGPN-9630 and No. 71 were found suitable for poor environmental conditions (below average stability). However, the genotype (GPN-9603 and GA-10 were suitable under favourable environmental conditions (above average stability). It is therefore worth to utilize these genotypes in the niger improvement programme to converge the stability characteristics of seed yield.

Key words: Genotypic adaptability, stability analysis, niger

Introduction

Adaptation of agricultural crops to their environments has been a key factor to enhance the seed yield, which have occurred since the spread of the crop to new environment (Evans, 1980). The process of adopting crop to gradually changing agronomic conditions has become more efficient through the use of systematic breeding programme and selection by breeders for high yield potential with wide adaptation. It has been estimated that the spectacular yield increase of crops during the second part of the 20th century have to be attributed in almost equal measure to application of recent breeding techniques and use of inputs.

Niger (*Guizotia abyssinica* Cass) is a hundred per cent cross-pollinated crop with presence of sporophytic protandrous self-incompatibility mechanism and hence homozygosity confers the adaptability to niger genotypes. However, consistency in performance of such genotypes across diverse environment is lacking. Under such circumstances it is necessary to identify newly developed genotypes, before their release for cultivation for high yield potentiality coupled with greater stability. Otherwise, specific genotypes can be suggested and recommended for specific environment so as to overcome total failure of the crop. Keeping this view in mind the present investigation was carried out.

Materials and methods

Ten elite genotypes with three checks were evaluated at ZARS, Igatpuri during *kharif* season of 1998, 1999, 2000, 2001 and 2003 under rainfed condition. Each genotype was soon in a plot size of 1.80 x 5.0 m uniformly during all the years. The recommended package of practises were followed to raise healthy crop stand. The observation were recorded per plot basis and converted into seed yield kg/ha. The data were subjected to analysis of stability as per the method outlined by Eberhart and Russel (1966). The phenotypic index was computed as per the method of Ram *et al.* (1970). The coefficient of determination and ecovalence were calculated as suggested by Bilbro and Ray (1976) and Becker (1981) respectively. The stability factor was calculated as suggested by Levis (1954).

Results and discussion

The analysis of variance for stability (Table 1) showed that mean difference between genotypes and environments were highly significant, indicating considerable variability among genotypes and environments. The significance of mean square due to G x E interaction indicates that the genotypes interacted considerably with the prevailing environmental condition. Similar type of results have also been reported by Upadhyaya (1993), Kumar *et al.* (1993), Hegde *et al.* (1999), Patil and Purkar (2000), Patil (2001), Duhoobn and Patil (2003). The G x E interaction was further partitioned into linear and nonlinear components. Since both the components were significant, the practical usefulness of prediction would depend on relative magnitude of two variances. In the present study, the linear component was in larger (more than twice larger) magnitude than nonlinear component, suggesting that the prediction of performance of a genotype can be possible across the environments. In prediction of performance, the nonlinear component may have its own role, since it is also significant.

Table 1 ANOVA for seed yield stability in niger genotypes

Source	d.f.	Mean sum of squares
Genotypes	12	19443.83**
Environments	4	57758.12**
G x E	48	1878.82**
Environment + (GxE)	52	6177.23**
Environment Linear	01	231032.50**
G x E Linear	12	828.86*
Pooled deviation	39	2057.35**
Pooled Error	120	471.30

** Significant at P=0.01

The environmental additives effect during different years expressed as deviation from grand mean (environmental index) indicated that 2003 had favourable season (78.92) followed by 2001 (34.46) and 2000 (11.69). However, the season during 1198 and 1999 were observed to be poorest.

Different measures of stability have been used by various workers. Earlier, Finlay and Wilkinson (1963) considered linear regression slope as a measure of stability. Further, Eberhart and Russel (1966) emphasized the need of considering both linear and nonlinear component of G x E interaction in judging the stability of a genotype. The coefficient of determination provides measure of variation (Bilbro and Ray, 1976) and ecovalence measures the *contribution of each genotype to the* G x E interaction sum of squares (Becker, 1981). Phenotypic index a new parameter is synonymous to mean performance. The magnitude of ecovalence generally depends on the magnitude of deviation mean square for the component which is due to linear regression, is usually small. However, in the present study in addition to the usual and regular three stability parameters i.e., mean performance ($\bar{x}$), regression coefficient (bi) and deviation from regression ($\bar{S}^2di$), other four parameters are considered (Table 2). They are phenotypic index (Pi) (Ram *et al.*, 1970), coefficient of determination (r^2) (Bilbro and Ray, 1976), ecovalence (Wi) (Becker, 1981) and stability factor ('S') (Levis, 1954). Considering these seven stability parameters, the stability of elite niger genotypes are accessed and promising ones will be promoted in further improvement programme. Accordingly, an ideal adaptable genotypes is one having high performance, a unit regression coefficient, coefficient of determination and stability factor and least or zero value of ecovalence and eviation from regression and lastly highest value of phenotypic index.

Table 2 Estimates of different stability parameters in niger genotypes

Genotype	Seed yield (kg/ha)						Phenotypic index Pi	Regression coefficient bi	Deviation from regression S^2di	Coefficient of determination r^2	Ecovalence Wi	'S' factor
	1998	1999	2000	2001	2003	Mean ($\bar{x}$)						
IGPN-9602	226	361	324	359	415	337	35.46	1.3242*	12.02*	0.8162	1.94	1.83
IGPN-9603	253	328	294	324	400	320	18.26	0.6996	0.981	0.7470	2.42	1.58
IGPN-9604	188	119	312	302	391	262	-39.13	1.3126*	53.49*	0.6561	9.46	2.07
IGPN-9605	230	184	305	307	300	265	-36.33	0.5818	21.19*	0.4861	5.03	1.30
IGPN-9606	302*	404	376*	398*	548*	406*	84.06	0.9496*	03.03	0.9739	0.84	1.01
IGPN-9609	120	213	333	346	280	258	-43.13	1.1428*	39.03*	0.6646	6.42	2.33
IGPN-9612	164	224	321	343	289	268	-33.33	0.9112*	22.89*	0.6823	3.73	1.76
IGPN-9613	107	252	227	281	278	229	-72.53	1.1688*	15.17*	0.7782	2.44	2.59
IGPN-9614	309*	437*	385*	424*	556*	422*	120.66	0.9479*	02.68	0.9511	0.55	1.09
IGPN-9630	253	371	359	383	474	368	66.46	1.1179*	08.55	1.8964	1.49	1.87
No.-71 (C)	126	239	229	278	313	237	-64.53	1.0154*	05.07	1.9233	0.81	2.48
GA-10 (C)	172	176	288	269	315	244	-57.53	0.8932	10.77*	0.8143	1.82	1.83
IGP-76 (C)	207	349	319	354	387	323	21.66	0.9350*	01.22	0.9090	1.09	1.06
Mean	204.3	281.3	313.2	336.0	380.4	303	0.00	1.0000				
SEm±	24.07	25.67	18.79	15.36	47.77	18.02						
CD (P=0.05)	70.26	74.69	54.75	43.50	139.0	54.09						
CV (%)	10.35	6.23	10.38	11.90	9.87							
Environmental index	-97.15	-27.92	11.69	34.46	78.92							

* Significant at five per cent level.

Significant regression coefficient (linear component) was shown by 10 genotypes and six genotypes have shown significant deviation from regression (nonlinear components), thereby indicating, the predominance of linear *component of G x E interaction, suggesting* possibility of prediction for seed yield. This is also confirmed from the combined analysis of variances table where the variance due to linear G x E interaction is larger (2.26 times more) in magnitude than the nonlinear G x E interaction variance. The similar results were also reported by Patil and Purkar (2000), Patil *et al.* (2000), Patil (2001), Duhoon and Patil (2002). However, only Joshi and Patil (1982) have reported contradictory to such results for seed yield in niger.

On examination of individual all seven stability parameters studied, the genotypes *viz.*, IGPN-9606, IGPN-9614 and IGP-76 were observed to be average adaptable genotypes as they have shown regression coefficient, coefficient of determination and stability factor near unity; as small as possible value of deviation from regression and ecovalence and higher value of phenotypic index. However, the genotypes IGPN-9603 and GA-10 have shown regression coefficient, coefficient of determination less than unity indicating their suitability under rich environmental conditions (above average stability). Simultaneously, the genotypes *viz.*, IGPN-9602, IGPN-9630 and No.-71 have shown regression coefficient and coefficient of determination values more than unity indicating their suitability for poor environmental conditions (below average stability). It is, therefore, concluded that these genotypes may be included in niger improvement programme to converge the stability characteristics of seed yield for development of stable variety adapted to wide range of environments and achieve quantum jump in niger production and productivity. Ultimately, which will help in boosting the economy of tribal poor farmer and to increase the share of niger among all oilseed crops in the oilseed scenario of the country.

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Histological and histochemical causes of induced male sterility in niger, *Guizotia abyssinica* Cass*

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Abstract

Histological and histochemical changes during microsporogensis were studied in the induced male sterile and normal anthers of niger (*Guizotia abyssinica* Cass). Both the induced male sterile anthers and normal anthers differed from each other in post-meiotic stages only. In GA_3 treated anthers, the tapetal cells in some of the anthers enlarged abnormally and exerted pressure while in many of the anthers the enlarged tapetum broke down and formed abnormal plasmodium, which resulted in crushing and degeneration of microspores. Middle wall, epidermis and endothecium enlarged after the completion of abortion process. In control plants, all these features were noticed to be normal. Histochemical localization of metabolites like total insoluble polysaccharides, proteins and RNA in the tapetum, wall layers, vascular bundles and connective tissues in anthers of induced male sterile plants showed lower content compared to normal anthers.

Key words: Niger, male sterility, histological, histochemical, tapetum

Introduction

Male sterility in crop plants is receiving increased attention for its usefulness in the production of hybrid seeds. Plant breeders were quick to use this type of sterility in their breeding programmes. Inspite of its wide spread use and economic importance, little is known about the nature, mode of action, or location of the induced male sterility factors.

The present study is an attempt made to understand histological and histochemical changes that are associated with GA_3 induced male sterility in niger (*Guizotia abyssinica* Cass). Male sterile and their fertile counterparts were studied in detail during microsporogensis using light microscopy adopting standard methods of investigation (Johansen, 1940; Jensen, 1962).

Material and methods

Seeds of N-71 were sown in plots in the Botany garden, during *kharif* season of year 2003, University of Agricultural Sciences (UAS) Dharwad, was selected for studying the mechanism of GA_3 induced pollen sterility. 200 ppm GA_3 was applied at three intervals with an interval of five days starting from first flower bud initiation induced sterility up to 88.9%. The water sprayed plants were considered as control.

GA_3 induced male sterile plants were studied for detailed microsporogensis using histological and histochemical methods and compared with their fertile counterparts. The flower buds were sampled in such a way to include all the representative stages in the developmental study of microsporogensis. They were categorized into different groups based on the size of bud and care was taken to see that, this included all the successive stages of microsporogensis. Flower buds of different sizes were fixed in standard fixatives depending on the metabolite to be localized. Formalin, acetic acid and ethanol (FAA) in the ratio of 1:1:18 by volume was used as fixative for localizing the total insoluble polysaccharides. Carnoy's B (6 parts of alcohol + 3 parts of Chloroform + 1 part of Acetic acid by volume) was used for fixing the tissues to localize nucleic acids and proteins. Subsequently, the materials were dehydrated using different ethanol: butanol grades (1:3,1:1,3:1) and embedded in paraffin 58-60°C using the paper boat technique (Jensen, 1962). Sections of 7-10 um thickness were taken and subjected to the histochemical tests listed in Table1. Successive stages of microsporogensis and pollen development of induced male sterile plants were compared with those of their respective normal plants under light microscope for histological and histochemical differences.

Results and discussion

The process of anther development did not differ from its fertile counterparts until the differentiation of PMCs into microspore tetrads.

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Table 1 Histochemical test adopted for different cellular metabolites in niger

Cellular metabolites	Fixative used	Test	Control	Colour indication
Total insoluble polysaccharides	FAA	Periodic acid Schiffs (PAS) test (Hotchkiss, 1948)	By omitting periodic acid step	Megenta
Proteins	Carnoy's-B	Mercuric bromophenol blue method (Mazia *et al.*, 1953)	Extraction of histones by 0.2 N Hcl	Deep blue
RNA	Carnoy's-B	Azure B method (Flax and Himes, 1952)		Dark blue/ purple

The young anther primordium exhibited homogeneous mass of tissue surrounded by epidermis. The primary archesporium differentiate hypodermally at four corners, dividing periclinally to produce primary parietal cells towards outside and primary sporogenous cells inside. The primary parietal cells further divided periclinally and anticlinally and differentiated into endothecium, middle layer and tapetum (Fig. 1). Simultaneously the primary sporogenous cells divided mitotically and gave rise to a mass of sporogenous tissue. Sporogenous tissue with further enlargement differentiated into pollen mother cells. The pollen mother cells divided meiotically there after and at the end of meiosis each PMC resulted into microspore tetrads (Fig. 6). Soon after the formation of tetrads, microspores were released into the anther locule (Figs. 2,7 and 13). This was followed by the development of pollen wall with distinct exine and intine around mature spores (Fig. 4). As the maturation of pollen grains further advanced, the septal cells between adjacent locules of each anther to be disappeared and formed a single locule (Fig. 4). Mature pollen grains were spherical with spinous exine. Dehiscence of anther wall occurred at the site where the adjacent locule joined together (Fig. 12). Premeiotic development in both the cases exhibited no differences indicating there was no effect of GA_3 at earlier stages. However, at post - meiotic stages, GA_3 treated plants recorded various degree of abnormalities and were very peculiar. The induced male sterile plants differed from their respective normal plants in tapetum and endothecium development and functioning from the microspore stage onwards. The tapetum, being the nutritive layer abruptly enlarged and encroached the developing microspores (Figs. 3, 8, 10 and 11). After attaining the maximum enlargement the tapetum disorganized and started degenerating along with the microspores in the subsequent stage.

Following the degeneration of tapetum and microspores, the wall layers *viz.* middle wall, endothecium and epidermis increased their size radially to fill the locular space (Fig. 5). Hypertrophy of the wall layers soon after the degeneration of microspores and tapetum followed a definite pattern in which middle wall layers enlarged more than endothecium and followed by epidermis (Fig. 5). Hence, the sequence of events observed in the development of anthers in male sterile plants suggests the fact that mal functioning of the tapetum is either through hypertrophy or remaining persistent beyond specified time as a causative agent in pollen abortion. The reports of Echlin (1971) who described the essential role of tapetum during microsporgenesis and Seetharam and KusumaKumari (1976) who opined that the abnormalities in tapetal cells led to the starvation and subsequent degeneration of meiocytes also support the phenomena observed in the present study.

In most of the cases, pollen abortion has been reasoned *out to be associated with some kind of tapetal* malfunctioning. Even the earliest studies such as that of Gates (1911) in *Oenothera* to more recent structural and or ultra structural studies on male sterility in different crop plants like rice (Yogeesha, 1991) support this view.

Histochemical studies: Histochemical localization of macromolecular substances such as polysaccharides, proteins and RNA in various development stages of anthers or pollen grain have been studied both in control and GA_3 treated anthers. Histochemical localization of tissue may perhaps be helpful in understanding the changes in the differentiation of various parts in anther development to find out the possible causes for induced male sterility.

Histochemical assessment made for total insoluble polysaccharides in fertile and induced male sterile anthers at premeiotic stage revealed that their accumulation was high in the wall layers and tapetum of fertile as well as sterile anthers. It depleted in control anthers at later PMCs while it remained persistent in male sterile anthers even after tetrad stage. Vittalaraya Kini (1981) recorded a similar pattern in sunflower and sugar beet respectively. The buildup and decline in polysaccharide content prior to and during meiosis is an important activity in preparation for later synthetic processes such as pollen wall formation and pollen starch accumulation. An increased accumulation of polysaccharide prior to meiosis in the wall layers of sterile anthers and its persistence even after

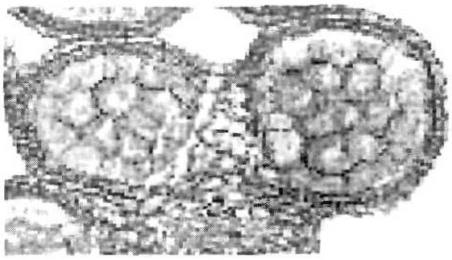
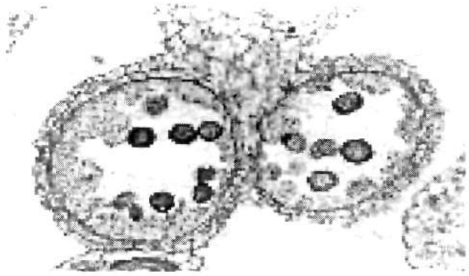


Plate - 1



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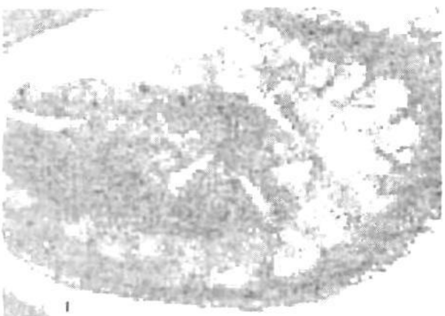

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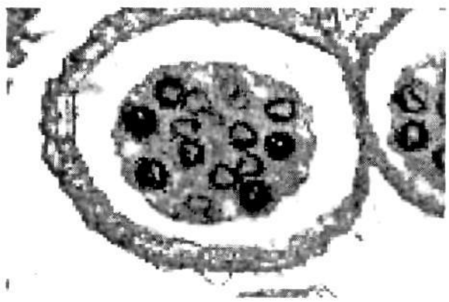

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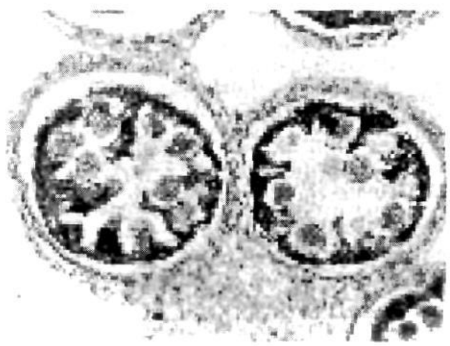
Plate - 5



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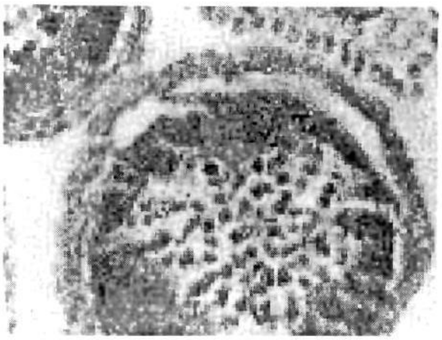

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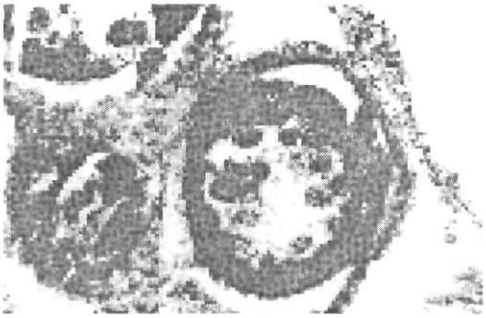

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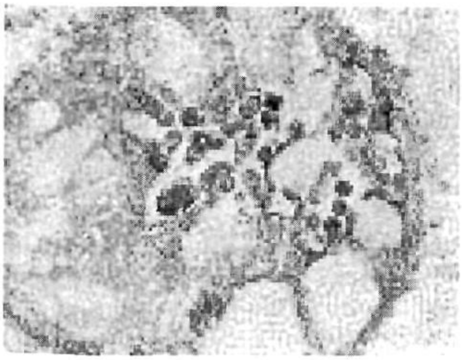

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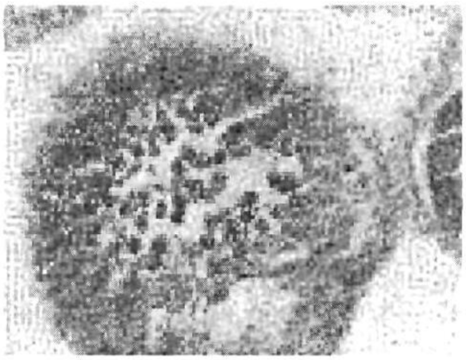

Plate - 10

Plate - 11

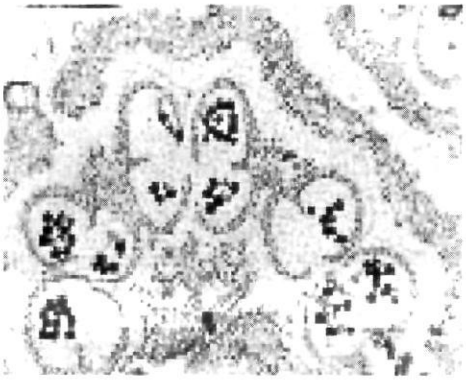

Plate - 12

the tetrad formation may be responsible for the hypertrophy of wall layers and tapetum. Non-utilization of polysaccharides in wall layers and tapetum even after the completion of meiosis can be assumed to have brought, about irregularities in the behaviour of these layers.

The role of protein in the induction of pollen sterility has been studied widely at enzymatic and amino acid levels (Kryzanek and Apltavenova, 1972; Rai and Stoskopf, 1974; Chauhan, 1976). In sorghum decrease in the quantity of soluble proteins was found to be the cause of pollen abortion (Tripathi *et al.*, 1981). However, increased amount of free amino acids resulted in failure of pollen formation in wheat (Kryzanek and Apltavenova, 1972).

Localization of protein molecules, in different cellular structures of fertile and sterile microsporangia varied considerably. During early stages of microsporogenesis, proteins level was very high in wall layers, sporogenous tissue, vascular bundles and connective tissues of sterile anthers. At PMC stage, level of protein in these layers remained intense in both control and sterile anthers. During meiosis and formation of tetrads same level was maintained. Most of the microspores released from fertile and few from the sterile anthers had high protein content. In the later stages of microsporogenesis outer wall layers, connective tissues and vascular strands were low in protein level and no differences were observed between control and sterile anthers. These results do not give a clear picture of the role of protein in pollen abortion and require further supplementation from quantification and biochemical experiments. However, one might suspect that decrease in the level of proteins in tapetum and meiocytes during meiotic and post-meiotic stages could have some influence on pollen abortion. Similar observations was made by Chauhan (1976) in all the parts of anther in the natural as well as chemically induced male sterile plants of *triticum* and vegetable crop.

The RNA content in induced male sterile plants decreased during later meiosis. Further, unlike in control, anthers change in the RNA content in the tapetal cells did not follow any regular pattern during post meiotic stages. Hence it may be assumed that increase in RNA content in the tapetal cells at meiotic stage (Fig. 9) and its persistence might have led to abnormality.

Histochemical studies that the inability of tapetum to mobilize important metabolites to the developing microspores causes their starvation and leads to abortion of induced male sterile anthers.

Legends

Plate 1 The mature PMCs of fertile anther surrounded by well differentiated wall layers. The cytoplasm of PMCs, tapetal cells, middle wall cells and endothecium has uniformly high concentration of polysaccharides. The PMCs are surrounded by relatively thick and prominent callose envelope (400X)

Plate 2 The anthers of sterile showing normal microspore tetrads. The middle wall layer is low in cytoplasmic polysaccharides while the tapetum, epidermis and endothecium are showing high concentrations (400X)

Plate 3 Microspores of fertile anther distributed through out the locule are high in their cytoplasmic polysaccharides. The tapetum has began to form plasmodium and its cytoplasm is extended into the anther locule. Middle wall layer and endothecium lack any starch substances (400X)

Plate 4 Tetralocular anther of sterile showing the developing microscpores. Note the formation of periplasmodial type of tapetum surrounding the microspores as in the case of fertile anthers. The endothecium microspores and tapetum are containing very high amount of cytoplasmic polysaccharides (400X)

Plate 5 The aborted locule of sterile anther showing the complete degeneration of tetrads and tapetum. Note the enlargement and vacuolization of middle wall layer, which is low in PAS positive substance. Epidermis and endothecium are intact and slightly increased in their radial thickness (400X)

Plate 6 Anthers of sterile showing high concentration of protein in PMCs, tapetum and wall layers. Note the partially differentiated connective tissue and vascular bundles (400X)

Plate 7 Fertile anther showing very high concentration of protein in tetrads and tapetum. Middle wall layer, endothecium and epidermis also contain relatively equal amount of proteins (400X)

Plate 8 Microspores in the normal fertile anthers surrounded by tapetal cytoplasm. The concentration of protein is higher in microspores and tapetum than that in the outer wall layers (400X)

Plate 9 The anthers of sterile showing microspores surrounded by protein rich tapetal cytoplasm. Note the middle wall, epidermis and endothecium are very much reduced and appear very thin (400X)

Plate 10 The tapetum and meiocytes are very high in the concentration of RNA. Note the slight enlargement in the radial thickness of the tapetum of outer locule and disturbances in the development in the locule (400X)

Plate 11 Microspores tetrads surrounded by enlarged tapetum in sterile anther locule. The RNA is intense in the microspores tetrads and high in tapetal cells. The outer wall layers are much reduced in thickness and indistinct (400X)

Plate 12 Part of the anther of sterile showing microspores surrounded by tapetal cytoplasm. Note the microspores and tapetum high in RNA activity. The outer wall layers are apparent (400X)

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Effect of GA_3 and surf excel on growth, flowering and seed set in niger, *Guizotia abyssinica* Cass*

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Abstract

Application of chemical hybridizing agents (CHA) induced pollen sterility to varying degrees depending on the nature of chemical, concentration, stage of spray and number of sprays. Application of GA_3 @ 200 ppm treated at three intervals at primary bud stage resulted in highest pollen sterility (88.9%) followed by GA_3 @ 200 ppm treated at two intervals at secondary bud stage (87.5%). The pollen sterility was very less during early stages of flowering and reached maximum values at 10-15 days after flowering and declined thereafter. The plant height, number of branches per plant, duration of flowering and days to maturity increased significantly due to GA_3 over control and decreased with Surf excel treatments. Flower size, seed number per capitula between unbagged control and GA_3 treated buds did not vary significantly with the application of GA_3.

Key words: Niger, chemical hybridizing agents, male sterility

Introduction

Niger (*Guizotia abyssinica* Cass) is an important minor oilseed crop cultivated in India for its edible oil for human consumption and oil cake for cattle feed (Getinet and Teklewold, 1995). Niger contributes about 3% to Indian oilseed production. Niger being a minor oilseed crop, very little attention has been made with respect to its genetic enhancement. Hence, identification and development of suitable cultivars possessing high yield potentiality is a major concern to enhance its productivity.

Niger, being a cross pollinated crop, is highly heterozygous and heterogenous but heterosis is not fully exploited either in the form of composites, improved populations or hybrids due to non-availability of cytoplasmic male sterile lines. Owing to small size and multihead inflorescence manual emasculation is impractical. So, there is an increasing need for a technique that would bring in easy emasculation, through induced pollen sterility. The present investigation was therefore under taken with a view to identity the chemical, concentration and stage of application to induce maximum male sterility.

Material and methods

Seeds of N-71 were sown in plots in the Botany Garden, University of Agricultural Sciences, Dharwad, maintaining a 30 cm distance between rows and 10 cm distance between plants. All recommended agronomic practices were followed during the crop growth period. The crop was raised during *kharif* season of year 2003.

Aqueous solution of two concentrations (200 and 250 ppm) of GA_3 and (1% and 1.5%) of Surf Excel were prepared in distilled water. A total of twenty-five plants were sprayed with each concentration at bud initiation stage. Another twenty five plants were sprayed with the same concentration of GA_3 and Surf excel solutions twice; first at bud initiation stage and the second at five days after first spray and thrice; first at bud initiation stage second at five days after first spray and the third at five days after second spray. The plants treated with water were considered as control.

The chemical treatments were given as shown in table1. Chemicals were sprayed on entire plant surface using a hand sprayer. At primary bud initiation stage plants with uniform bud size were selected and marked for different GA_3 and Surf excel treatments in the following concentrations.

The experiment thus involved 13 treatments (four concentrations x three days of application and one control). These treatments are referred as T_0 to T_{12} as shown in Table1. Spraying was done under clear, sunny and hot days with a hand sprayer till the solution run off from the plant.

Data on plant height, number of branches, flower size, duration of flowering, days to maturity and pollen sterility were recorded. Some of the inflorescence of treated and untreated plants were covered with butter paper bags to check the seed set. These data were statistically analysed by using Student's t test.

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Pollen sterility **at anthesis** was recorded using pollen germination **media with the following** compositions:

Boric acid	-	200 mg/litre
Potassium nitrate	-	200 mg /litre
Magnesium sulphate	-	200 mg /litre
Calcium nitrate	-	200 mg /litre
Poly ethylene glycol	-	223.66g/litre
Sucrose	-	15%
Stigma extract	-	one stigmas

$$\text{Per cent pollen germinated} = \frac{\text{Number of pollens germinated}}{\text{Total number of pollen observed}} \times 100$$

Pollen grains were collected separately from primary and secondary capitula. Ungerminated and germinated pollens were counted and were used for calculating per cent pollen sterility.

Results and discussion

Morphological changes: Plants sprayed with different concentrations of the GA_3 displayed *increase in* height, number of branches, duration of flowering and days to maturity while the Surf Excel treatments displayed *reduction in them.*

There was a significant increase in plant height over control in all the GA_3 treatments similar to those observed by the Vittalaraya Kini (1981) *in sunflower*, but there was a decrease in plant height in Surf excel treatments.

Table 1 **Influence of CHAs on growth parameter in niger**

Treatment	Plant height (cm)	No. of branches	Flower size (cm)	Duration of flowering	Days to maturity	*Pollen sterility (%)*		*Seeds/capitula*	
						Primary bud	Secondary bud	Unbagged	Bagged
T_0 Control	58^{e}	9^{e}	1.02^{a}	19^{e}	89^{c}	18.7^{h}	27.1^{f}	49^{ab}	8^{a}
T_1 : GA_3 @ 200 ppm applied at once	80^{d}	19^{c}	0.76^{a}	33^{a}	94^{b}	73.0^{d}	71.3^{d}	42^{d}	1^{c}
T_2 : GA_3 @ 200 ppm applied at two intervals	85^{c}	16^{d}	0.82^{a}	28^{cd}	95^{b}	85.7^{b}	87.5^{a}	48^{b}	0^{c}
T_3 : GA_3 @ 200 ppm applied at three intervals	87^{c}	20^{ab}	0.84^{a}	31^{b}	99^{a}	88.9^{a}	85.1^{a}	45^{c}	0^{c}
T_4 : GA_3 @ 250 ppm applied at once	94^{d}	22^{a}	0.89^{a}	26^{d}	91^{c}	81.0^{c}	78.8^{b}	51^{a}	0^{c}
T_5 : GA_3 @ 250 ppm applied at two intervals	86^{c}	18^{bc}	0.74^{a}	29^{bc}	86^{d}	74.0^{d}	68.8^{d}	49^{ab}	0^{c}
T_6 : GA_3 @ 250 ppm applied at three intervals	98^{a}	16^{d}	0.72^{a}	27^{d}	84^{e}	69.6^{e}	75.5^{c}	47^{b}	0^{c}
T_7 : Surf excel @ 1% applied at once	50^{f}	8^{ef}	0.70^{a}	15^{f}	86^{d}	62.8^{f}	58.5^{e}	19^{d}	3^{b}
T_8 : Surf excel @ 1% applied at two intervals	45^{g}	7^{f}	0.72^{a}	13^{fg}	76^{g}	52.8^{g}	*	14^{e}	1^{c}
T_9 : *Surf excel @ 1% applied at three intervals*	42^{h}	9^{e}	0.70^{a}	12^{g}	80^{f}	*	*	*	*
T_{10} : Surf excel @ 1.5% applied at once	*	*	*	*	*	*	*	*	*
T_{11} : Surf excel @ 1.5% applied at two intervals	*	*	*	*	*	*	*	*	*
T_{12} : Surf excel @ 1.5% applied at three intervals	*	*	*	*	*	*	*	*	*

t (P=0.05) 2.57
Values with same super script do not differ significantly.
* = Plant mortality

Size of floral bud did not vary significantly with the application of chemicals but slight reduction in inflorescence size was observed in all treated plants as similar to those *observed by Vittalaraya Kini* (1981) *in* sunflower. No malformations were noticed.

Duration of flowers and days to maturity showed significant *differences in all* GA_3 *treated plants compared to normal.*

In all the GA_3 *treated plants there was delay in opening of* flowers and this is because of increased vegetative growth in terms of plants height and number of branches in GA_3 treated plants and accordingly duration of flowering and days to maturity were delayed by 5-11 days as observed by Baydar and Gokmen (2003) in safflower. However, in Surf excel treatment though there was a delay in opening of flower (Chauhan and Singh, 2003) the duration of flowers was reduced by 2-6 days and in accordance the days to maturity was advanced by 1-4 days.

Seed set in unbagged untreated i.e in control (48seeds/capitula) and unbagged treated buds i.e in GA_3 treated plants (42-51seeds/capitula) were observed. Less seed set (19 seeds/capitula) was observed in Surf excel treated plants it may be due to abnormal flower development. When treated buds were bagged, no seed set was seen and only in few cases very few seeds (2-4seeds/capitula) were seen. The seed count in treated unbagged plants indicated that, though male sterility is induced, it did not affect female fertility.

Pollen sterility: Spraying GA_3 at a concentration of 200 ppm at bud initiation stage at three intervals with a gap of five days could induce male sterility as high as 88.9% in the primary bud. When the same concentration was used at same stage for once, it showed 73% in the primary bud. The other treatment that could give good amount of male sterile flowers was use of 200 ppm GA_3 during star bud stage at two intervals which gave 87.5% 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 (1975) and Vittalaraya Kini (1981) and in niger by Veerakumar (2002). Concentration of GA3 seems to have a major role in induction of pollen sterility. GA_3 treatments at the rate of 200 ppm at two and three intervals affected the pollen sterility significantly but differed significantly from other treatments. This seems to be contrary with results of Seetharam and Kusumakumari (1975) who recommended a lower concentration than 150 ppm for induction of maximum pollen sterility in sunflower. Niger may require higher concentration of GA_3 for inducing male sterility. Regarding stage of application spraying at bud initiation stage proves to be better. Works of Schuster (1969) and Seetharam and Kusumakumari (1975) also supports this. Since niger have multiheaded inflorescence and continuous flowering nature, each plant requires more than one treatment to induce pollen sterility in all the plants.

A single spray of Surf excel resulted in inducing reasonable level of pollen sterility at concentration of 1 %. However, spraying it for three days or use of 1.5% solution proved to be adverse to 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 like anti deposition agents, bleaching agents, organic sequestering agents and enzymes along with sodium carbonate and sodium borate in the detergent, 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 induction of very high pollen sterility at concentrations as high as 3 to 6% of detergent. Use of the detergent at lower concentrations might be successful for induction of pollen sterility without affecting the plant. Based on the present investigation detergents are not suitable as CHA in niger.

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Short communication

Genetic analysis of selfed and biparental populations for pod yield, yield components and foliar diseases in a groundnut cross, *Arachis hypogaea* L.

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Groundnut is most likely to be affected by important foliar diseases like early and late leaf spot and the pest *Spodoptera litura*, responsible for reduction in crop yields. Earlier efforts to combine pod yield with resistance to foliar disease resistance have become less successful as resistance accompanied with poor pod features. This is mainly because of existence of inverse relationships as a result of tight linkages observed between resistance factors and pod yield and also with important yield traits (Bhat *et al.*, 1995; Gowda *et al.*,1996), which restrict the release of complete variability normally through pedigree breeding. On the other hand recurrent selection as carried out by Gouk *et al.*, 1986, Halward and Wynne, 1992 to combine foliar disease resistance with pod yield encourages to adopt intermating even in a highly self pollinated crop like groundnut. Intermating among the segregants in a broad based cross provides an opportunity to break tight linkages, release concealed variability and alter the nature of associations between the traits, so that selection can be more effective in combining desirable traits. An attempt has been made in the present study to assess the extent of genetic variability for different characters in selfed and biparental populations of a groundnut cross.

The experimental materials comprised of two parents TAG-24 and Dh 22 with diverse morphological characters, their F2 and biparental populations (BIP-I). TAG 24 is a recently released variety for summer irrigated situations in Karnataka which has dwarf plant type, earliness and dark green foliage but is highly susceptible to early (ELS) and late leaf spot (LLS) when grown in *kharif* and summer grown seed is a problem for perpetuation of the variety. Whereas the other parent Dh 22 (a derivative of resistant parent ICGV 87165) is an advanced breeding line having high amount of resistance to above foliar diseases. The purpose of present study has been to combine foliar disease resistance of Dh 22 into the background of TAG 24 through intermating so that the resultant genotype can serve as a dual season variety. In F_2 of this cross, 60 paired crosses were effected between the plants exhibiting susceptibility (TAG 24 type) and resistance to foliar diseases (Dh 22 type) in the crossing block. The crossed seeds were bulked and then advanced by selfing to form the biparental series (BIP-I). The remnant F_2 seeds formed the Selfing series for the comparison. Sufficient care had been taken to maintain at least 750 plants in both the series for proper expression of the traits. The two populations along with their parents were sown at the Research block of Oilseeds Scheme, Main Agricultural Research Station, UAS, Dharwad during *kharif* 2001. The plot size consisted of three rows of five metre length for parents, while fifteen rows for F_2 and BIP-1 spaced at 30 and 10 cm between rows and plants, respectively. The observations were recorded on 15 plants in case of parents and 250 plants in F_2 and BIP-I chosen randomly for 13 quantitative traits. The data was subjected to a standard statistical procedure to work out different genetic parameters.

Mean performance of BIP-I was superior compared to its corresponding F_2 in respect of plant height, pod yield, shelling percentage, per cent sound mature kernels and 100-kernel weight (Table 1). The shifts in mean values of the characters due to intermatting have also been reported by Monteverde-Penso *et al.*, 1987; Parameshwarappa *et al.*, 1997. The characters *viz.*, pod number, kernel yield, oil content , *Spodoptera* damage and ELS did not vary between the populations for the mean performance. The lack of shifts in mean values of these characters between BIP-I and F_2 could be attributed to operation of strong linkages between the characters. Although, lower mean values for LLS has been recorded in BIP-I it is being considered as desirable indicating disease resistance.

The correlations indicated that kernel yield and oil content correlated negatively with each other in both the generations (Table 2). However, the magnitude of association between these two traits appeared to have been reduced to non-significance in BIP-I. This could be a positive trend since improvement for one trait may not come in the way of the other and simultaneous improvement of the traits is possible (Parameshwarappa *et al.*, 1997). A similar shift has also been observed in respect of the associations between shelling percent and kernel weight, oil content and SMK %, late leaf spot damage and SMK %, pod yield and oil content and SMK

% and plant height offering better scope for simultaneous improvement of these traits. The change in pattern of associations of ELS or LLS with pod traits like shelling percent, kernel weight and SMK % was not perceptible but has been encouraging to initiate studies with crosses having different genetic background. However, associations between oil content and days to maturity, oil content and shelling per cent observed to have been shifted in opposite direction from positive significance to negative significance indicating the breakage of coupling phase linkages.

Table 1 Mean values of characters in F_2 and biparental populations of TAG 24 x Dh 22 groundnut cross

Entry/Cross	Plant height (cm)	No. of branches	Maturity (days)	Pods/ plant	Pod yield/ plant (g)	Kernel yield (g)	Shelling (%)	SMK (%)	100 kernel weight (g)	Oil content (%)	*S.litura* score (1-5)	Early leaf spot (1-9)	Late leaf spot (1-9)
TAG 24	8.74	5.43	96.00	18.23	16.80	11.83	70.81	85.16	34.70	48.02	3.20	5.20	4.92
Dh 22	13.23	5.02	96.00	14.62	12.53	8.47	67.50	63.78	29.20	46.80	0.92	2.21	2.50
F_2 (TAG 24 x Dh 22)	9.7± 0.25	5.3± 0.1	96.1±. 0.1	16.2± 0.4	13.0± 0.3	9.5± 0.2	72.9± 0.4	72.8± 0.7	32.3± 0.7	47.1± 0.15	1.7± 0.1	4.62± 0.1	4.5± 0.1
BIP-1 (TAG 24 x Dh22)	11.3 ± .25	5.6± 0.1	95.0± 0.1	17.7± 0.3	15.2± 0.3	9.8± 0.2	78.9±0.3	78.3± 0.4	35.9± 0.6	46.3± 0.6	1.7± 0.1	4.4± 0.2	3.5± 0.2

Table 2 Phenotypic correlations among different characters in the F_2 and BIPs of the cross TAG 24 x Dh 22

Character	Population	Plant height	No. of branches	Pods/ plant	Shelling (%)	100-kernel weight	SMK	Oil content	*Spodoptera* score	ELS	LLS	Pod yield	Kernel yield
Days to maturity	F_2	0.110	-0.042	0.071	0.005	-0.045	-0.064	0.179**	0.039	-0.088	-0.069	0.064	0.069
	BIP I	0.096	0.012	0.086	0.005	-0.005	0.122	-0.376**	0.016	-0.006	-0.047	0.108	0.115
Plant height (cm)	F_2		0.065	0.048	0.081	-0.181**	-0.194**	0.136*	0.053	-0.120	-0.038	0.088	0.101
	BIP I		0.194**	0.136*	-0.120*	0.257**	0.121	0.099	0.192**	0.102	0.042	0.093	0.071
No.of branches	F_2			-0.106	-0.165	0.035	0.089	0.325**	0.013	0.114	-0.023	-0.061	-0.089
	BIP I			0.034	0.110	0.184**	0.188**	0.005	0.998**	0.013	0.045	-0.006	-0.044
Pod no per plant	F_2				0.111	-0.001	-0.030	-0.522**	0.109	-0.027	-0.022	0.865**	0.856**
	BIP I				-0.044	0.037	0.085	0.257**	0.030	0.000	-0.078	0.889**	0.765**
Shelling (%)	F_2					-0.025	-0.021	0.218**	0.175**	-0.117	-0.047	0.084	0.282**
	BIP I					0.150*	0.169**	-0.348**	0.103	0.053	0.012	-0.012	0.093
100-kernel weight (g)	F_2						0.932**	-0.055	-0.088	-0.146*	-0.291**	-0.227**	-0.216**
	BIP I						0.764**	0.078	0.184**	-0.281**	-0.137*	0.073	0.058
SMK (%)	F_2							-0.229**	0.038	-0.082	-0.195**	-0.280**	-0.269**
	BIP I							-0.048	0.187**	-0.142*	-0.043	0.121*	0.118
Oil content (%)	F_2								-0.103	0.153*	-0.115	-0.450**	-0.386**
	BIP I								0.005	0.070	0.098	0.027	-0.034
Spodoptera incidence (1-5 grade)	F_2									-0.034	0.035	0.082	0.105
	BIP I									0.010	0.039	-0.009	-0.045
ELS	F_2										0.273**	-0.051	-0.079
	BIP I										0.401**	-0.057	-0.017
LLS	F_2											0.016	0.003
	BIP I											-0.102	-0.133
Pod yield (g)	F_2												0.976**
	BIP I												0.847**

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

Among the yield components pod number and pod yield have shown strong positive associations with kernel yield in both the populations, which imply the importance of these traits in getting higher kernel yield. A similar trend being noticed in the correlation between 100-kernel weight and percent SMK. Shifts in the associations of other characters have been either in magnitude or in direction or both. To obtain shifts both in desirable direction as well as in magnitude perhaps require more than one cycle of intermating followed by stringent selections as adopted by Pustovoit (1967) in sunflower. Since groundnut is a highly self pollinated crop, the chances of hybridization and seed set are low, intermating may not be a practical proposition. However, one can adopt a limited *inter se* crossing of selected segregants based on preliminary screening.

Thus, the present investigation has been able to reveal enhanced genetic variability in the biparental population for plant height, pod number, pod yield, oil content, early and late leaf spot when compared to its corresponding F_2 population. While the characters *viz.*, days to maturity, shelling percentage, SMK %, kernel weight and damage due to *S. litura* showed the least response to intermating indicating that genetic background of the material used in the studies is important. The changes brought about in release of hidden variability for the characters is of genetic in nature and the study encourages adoption of intermating for simultaneous improvement of correlated traits.

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Short communication

Studies on genetic divergence in spanish bunch groundnut, *Arachis hypogaea* L. genotypes

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The success of hybridization in self-pollinated crops like groundnut mainly depends on the genetic divergence of the parents involved in the hybridization programme. The diversity not only results in genetic variation but also provides new recombination of genes in the gene pool. Genetic diversity plays an important role in plant breeding because hybrids between lines of diverse origin generally displays a greater heterosis than those between closely related genotypes. Therefore, the divergence studies aid in selection of divergent parents for hybridization. The present investigation with 64 spanish bunch genotypes of groundnut were grown in a Randomized Block Design with three replications during *rabi*, 2001. In each replication each genotype was represented by 3 rows of 3 m length with a spacing of 30 x 10 cm. Observations were recorded on randomly selected five plants in each genotype in each replication for all characters except days to 50 % flowering and days to maturity which were recorded on per plot basis. The analysis of variance was carried out for all the characters individually. Multivariate analysis was done as per Mahalanobis D^2 statistics (1936) as described by Rao (1952) and the genotypes were grouped into different clusters following Tocher's method described by Rao (1952).

The analysis of variance showed significant differences among the genotypes for all the characters studied, indicating genetic differences among the genotypes. Based on divergence and magnitude of D^2 values, 64 genotypes were grouped into 10 clusters (Table 1). Cluster I emerged out as the largest cluster with 13 genotypes representing different eco-geographical regions of the country and the world. Next to cluster I, cluster III consisted of 10 genotypes followed by cluster II (8), VIII (7), V and VI (6 each), IX (5) and clusters IV, VII and X with three genotypes each. The genotypes were distributed randomly in different clusters irrespective of geographic origin. Further, the grouping of genotypes did not showed any relationship between genetic divergence and geographic diversity. Similar kind of non-correspondence of genetic and geographic diversity has also been reported by Golakia and Makne (1991), Reddy and Reddy (1993), Nayak and Patra (1997) and Venkataravana *et al.* (2000). Such lack of relationship between genetic and geographic diversity may be attributed to genetic drifts and selection in different environments that may cause greater genetic diversity than geographic distance (Arunachalam *et al.*, 1981).

The inter cluster distances were greater than intra cluster distances, revealing that considerable amount of genetic diversity existed among the genotypes studied (Table 2). The intra-cluster generalized distance was maximum for cluster X (144.07) and minimum for cluster IV (17.59). The highest inter-cluster distance was recorded between cluster IV and X followed by cluster VII and X and cluster II and X. The data on the character means for 10 clusters were furnished in Table 3. Cluster means for different characters showed considerable differences between the clusters for all the characters. The genotypes of cluster II had maximum values for pods/plant, mature pods/plant and low value for days to maturity, whereas cluster III registered high values for days to maturity. Similarly, cluster V recorded the high values for oil content, cluster VII for height, cluster VIII for harvest index, cluster IX for kernel yield/plant, shelling percentage and early flowering. However, the genotypes of cluster X recorded high mean seed weight. It is suggested that crosses could be effected among the selected genotypes of divergent clusters for improving economic characters as well as to recover potential transgressive segregants for further selection and to develop high yielding varieties of groundnut.

Harvest index (40.3), 100-seed weight (28.8%) and shelling percentage (16.1%) contributed maximum towards genetic divergence in this Spanish bunch group. Other characters have contributed very less towards divergence. However, days to 50% flowering and pod yield/plant showed no contribution towards the genetic diversity. Venkateswarlu (1988) also reported that harvest index was the potential factor for divergence (21.5%) followed by 100-seed weight (20.4%). Therefore, it is clear that the above three characters studied need greater attention for further improvement of genotypes in groundnut.

Table 1 Group constellation of the groundnut spanish bunch genotypes

Cluster	No. of genotypes	Genotypes included
I	13	BARBESTON, ZM-1108, K-1128, AH-7322, Acc. No. 416, 418, J-11, TMV 2 / EC 2113, AK-12-24-119, RM-4, K-3/ICGV-2716, Acc. No. 3274, Acc. No. 63-106
II	8	AH-3490, NG 387-B, Acc. No. 226, NG-21, MASANI, NC-1308, KG-61-99, X-1-21-B-B
III	10	Acc. No. 10-5, NCAC-251, RS-30, RPM-691, K-134/ICG/62/64, TCGS-110, TCGS-325, TCGS-88, TCGS-37, K-153
IV	3	TMV-2, Acc. No. 7-1, EC-1676
V	6	CHIKODI, K-1268, RPM-189, tcgs-320, k-134, Acc. No. 318
VI	6	Acc. No. 61-52, ZM-2180, TG-9, EC-7986, LOCAL RED, TG-26
VII	3	DAS-016, NG-5144, Acc. No. 419
VIII	7	K-176, FI-5, FIAZAPUR, LE-39, Acc. No. 13-10, NAN-602, AM-12-24-2
IX	5	NCAC-2753, U-44-27, TG-3, K-1238, TPT-4
X	3	MANFREDI, TCGS-344, TCGS-596

Table 2 Inter-cluster and intra-cluster (diagonal) D^2 and D values (in parentheses) of 64 genotypes of Spanish bunch

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X
I	57.88 (7.61)	75.55 (8.69)	81.78 (9.04)	109.12 (10.45)	124.79 (11.17)	136.80 (11.70)	142.92 (11.96)	157.53 (12.55)	237.10 (15.40)	399.32 (19.98)
II		39.70 (6.30)	92.28 (9.61)	159.11 (12.61)	208.46 (14.44)	180.93 (13.15)	222.55 (14.92)	97.38 (9.86)	198.05 (14.07)	504.32 (22.46)
III			45.31 (6.73)	179.02 (13.38)	117.53 (10.84)	122.57 (11.07)	234.18 (15.30)	127.01 (11.27)	122.43 (11.07)	276.39 (16.63)
IV				17.59 (4.19)	119.38 (10.93)	300.12 (17.32)	194.04 (13.93)	368.91 (19.21)	455.78 (21.35)	578.40 (24.05)
V					69.69 (8.35)	186.81 (13.67)	212.49 (14.58)	324.43 (18.01)	301.54 (17.37)	275.46 (16.60)
VI						89.19 (9.44)	160.28 (12.66)	176.17 (13.27)	200.82 (14.17)	265.76 (16.30)
VII							66.68 (8.17)	333.61 (18.27)	471.50 (21.71)	514.79 (22.69)
VIII								51.44 (7.17)	125.98 (11.22)	445.34 (21.10)
IX									54.20 (7.36)	268.63 (16.39)
X										144.07 (12.00)

Table 3 Cluster means for twelve characters in 64 genotypes of Spanish bunch groundnuts

Cluster	Days to 50% flowering	Primary branches/ plant (n+1)	Days to maturity	Plant height (length of main axis)	Pods/ plant	Mature pods/ plant	Kernel yield/plant (g)	Shelling percentage	100-seed weight (g)	Harvest index (%)	Oil content (%)	Pod yield/ plant (g)
I	33.76	4.13	112.80	15.67	16.22	12.59	7.74	68.98	36.50	38.92	40.74	11.20
II	32.96	4.05	111.04	15.02	17.64	14.35	9.06	71.23	33.37	44.24	41.11	12.73
III	33.97	4.19	113.40	15.41	15.58	11.93	10.05	71.51	41.32	41.92	43.47	13.96
IV	33.67	4.18	113.33	15.00	16.17	12.58	7.75	72.97	32.11	30.64	42.98	10.62
V	34.11	4.40	113.22	14.73	15.20	10.44	7.77	71.27	42.46	31.98	44.92	10.89
VI	33.06	4.12	111.06	17.06	15.29	11.43	7.97	62.47	43.84	41.27	41.96	12.80
VII	33.22	4.20	111.56	18.46	16.84	13.19	6.34	57.62	35.48	34.33	41.25	10.98
VIII	33.38	4.13	111.24	14.23	17.09	13.33	8.98	69.41	37.77	51.22	39.24	12.96
IX	32.40	4.11	111.60	16.09	16.75	13.39	11.67	73.74	47.89	49.05	41.94	15.55
X	33.33	4.78	113.00	15.07	15.66	9.55	9.10	69.11	58.05	37.07	43.12	13.26

The criterion used for selection of genotypes as parents for hybridization using D^2 analysis is the inter-cluster distances. The success of hybridization depends on the genetic diversity among the parents. The genotypes included in clusters with maximum inter-cluster distance are genetically more divergent. In the present study, the cluster IV and X showed maximum divergence. Hence, it is expected that hybridization between the genotypes of these two divergent clusters will lead to high heterotic effects with better segregants in groundnut improvement.

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Short communication

Nodulation in groundnut, *Arachis hypogaea* L. as influenced by weed management practices and intercropping with sunflower, *Helianthus annuus* L. during *kharif*[*]

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Groundnut is a leguminous plant which fixes atmospheric nitrogen in the root nodules. Mechanical method of weed control is a common practice followed in groundnut. However, this method is time taking, expensive and tedious. Integrated approach by combination of herbicides with hand weeding will help the crop for extended weed free condition. But, there are reports that herbicides application to soil will effect biological activity in soil. Groundnut being short stature crop, tall stature crop like sunflower can be successfully intercropped with groundnut to increase the productivity of oilseeds. Due to competition between groundnut and sunflower root nodulation may be affected. Keeping these in view the present study was conducted to find the influence of weed management practices and groundnut + sunflower intercropping during *kharif* on nodulation in groundnut.

The field experiment was conducted during *kharif* seasons of 1999 and 2000 at S.V. Agricultural College Farm, Tirupati, Andhra Pradesh. The experiment site was sandy clay loam in texture, slightly alkaline in pH (7.9) low in organic carbon (0.32) and available N (175 kg/ha) medium in available P_2O_5 (23.5 kg/ha) and K_2O (173 kg/ha). During the crop period, a total rainfall of 274 mm was received in 20 rainy days during 1999 and 569 mm in 32 rainy days during 2000. During both the years to facilitate staggered sowing of sunflower as an intercrop at two weeks after sowing (WAS) of groundnut, irrigation was given to the entire experimental field. Subsequently two protective irrigations were also given during both the years. There were three main treatments and eight sub-treatments (Table 1).

Table 1 **Number and dry weight (mg) of nodules/plant of groundnut as influenced by weed management practices and cropping systems, *kharif*, 1999, 2000 and pooled**

Treatment	Nodules/plant						Dry weight (mg) of nodules/plant					
	1999		2000		Pooled		1999		2000		Pooled	
	25 DAS	*50 DAS*	*25 DAS*	*50 DAS*	*25 DAS*	*50 DAS*	*25 DAS*	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS
Weed management												
M_1 : HW at 20 and 35 DAS	18.6	28.4	17.9	32.1	18.3	30.3	13.6	33.5	13.1	40.4	13.4	37.0
M_2 : Metilachlor at 1 kg a.i./ha as PE+HW at 35 DAS	18.6	29.5	18.1	32.6	18.4	31.1	13.7	34.0	13.5	41.2	13.6	37.6
M_3 : Pendimethalin at 0.75 kg a.i./ha as PE+HW at 35 DAS	18.9	29.3	18.0	31.8	18.5	30.6	14.0	33.8	13.4	40.2	13.7	37.0
SEm±	0.28	0.20	0.10	0.11	0.17	0.11	0.11	0.11	0.13	0.20	0.76	0.85
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cropping system												
S_1 : Sole GN	19.5	30.5	18.7	33.8	19.1	32.2	14.9	37.3	14.0	44.2	14.5	40.8
S_2 : Sole SF	-	-	-	-	-	-	-	-	-	-		
S_3 : GN+SF 4:1	17.1	25.9	16.5	29.3	16.8	27.6	12.6	25.9	11.9	31.7	12.3	28.8
S_4 : GN+SF 6:1	17.7	26.9	17.0	29.6	17.4	28.3	12.8	28.0	12.7	34.5	12.8	31.3
S_5 : GN+SF 4:1 (SF sowing at 2WAS of GN)	19.1	30.1	18.3	32.9	18.7	31.5	13.8	36.4	13.7	42.5	13.5	39.5
S_6 : GN+SF 4:1 (SF sowing at 3 WAS of GN)	19.0	30.2	18.7	33.3	18.9	31.8	14.2	36.3	13.8	43.5	14.0	39.9
S_7 : GN+SF 6:1 (SF sowing at 2 WAS of GN)	19.1	29.8	18.3	33.5	18.7	31.7	13.9	35.9	13.7	43.9	13.8	39.9
S_8 : GN+SF 6:1 (SF sowing at 3 WAS of GN)	19.4	30.1	18.7	32.9	19.0	31.8	14.5	36.4	13.5	43.8	14.2	40.1
SEm±	0.35	0.51	0.3	0.51	0.27	0.37	0.26	0.57	0.28	0.64	0.27	1.18
CD (P=0.05)	1.0	1.5	0.9	1.5	0.8	1.1	0.7	1.6	0.8	1.8	0.8	3.4

DAS : Days after sowing; HW : Hand weeding; PE : Pre-emergence; GN : Groundnut; SF : Sunflower

[*] Part of the Ph.D. Thesis submitted by the senior author to the Acharya N.G. Ranga Agricultural University, Hyderabad.

The crop was raised in gross plot size of 7.7 x 4 m. Sole groundnut (Variety 'Tirupati-1', a spanish bunch) was sown at a spacing of 30 x 10 cm. In groundnut + sunflower intercropping, 100% population of sole groundnut and 75% of sole sunflower was maintained with inter row spacing of 30 cm and by altering intra row spacing. The root nodules of five plants were carefully removed and counted at 25 and 50 DAS, averaged and expressed as number of root nodules/plant. A total quantity of 20 N + 40 P_2O_5 + 50 K_2O kg/ha as basal and 50 kg gypsum was applied at pegging stage in sole groundnut. In groundnut + sunflower intercropping system, 75% of recommended dose of fertilizer of sole sunflower was applied (15N + 45 P_2O_5 + 22.5 K_2O kg/ha as basal, top dressing of 20 kg N/ha at 25-30 DAS and 20 kg N/ha at two weeks there after was applied) as 75% of population was maintained, along with 100% recommended dose of fertilizer to groundnut. The separated root nodules were oven dried at 60°C to constant weight and weights were recorded, averaged and expressed as dry weight of root nodules in mg/plant.

Root nodulation tended to increase progressively from 25 DAS to 50 DAS, regardless of herbicides applied (Table 1). Metolachlor and pendimenthalin applied as pre-emergence did not have any adverse effect on nodule number and dry weight. This might be due to the reason that soil applied herbicides remained active upto 4 cm depth of soil. Rethinam *et al.* (1976), Yaduraju *et al.* (1980), Malavia and Patel (1986) and Prabhakar (1991) were of the opinion that herbicides do not cause any harm to root nodulation in groundnut.

In pooled analysis, higher number and dry weigh of nodules/plant at 25 and 50 DAS were with sole groundnut, but comparable with staggered sowing of sunflower 2 or 3 WAS of groundnut (GN+SF 4:1 or 6:1) and significantly lower number and dry weight of nodules were observed with simultaneous intercropping (GN+SF 4:1 or 6:1) (Table 1). These results are in accordance with findings of Surekha (1992). It could be concluded that in simultaneous sowing of groundnut + sunflower intercropping, sunflower might have affected root nodulation of groundnut due to allelopathic effect. While sunflower did not affect nodulation of groundnut in staggered sowing of sunflower 2 or 3 weeks after sowing of groundnut due to delay in sowing of sunflower. Hence, staggered sowing of sunflower 2 or 3 weeks after sowing of groundnut in 4:1 or 6:1 row ratios will not affect nodulation of groundnut.

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Short communication

Response of groundnut, *Arachis hypogaea* L. to micro-irrigation and mulches under lateritic soils of Konkan (Maharashtra)

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Groundnut (*Arachis hypogaea* L.) is an important oilseed crop of tropical and subtropical regions of the world. India holds a premier position in the global oilseed scenario accounting for 19 per cent of total area and 9% of the total oilseed production (Hegde, 2000). In Maharashtra area under groundnut is 4.40 lakh ha and production is 5.58 lakh tonnes. In Konkan regions, there is a great scope for boosting the yield of groundnut crop by intensive application of technologies through micro-irrigation and mulching. Lack of timely irrigation and use of improper irrigation methods are the main reasons for low productivity of *rabi* groundnut in this region. Over or under irrigation with traditional method leads to lower the productivity of this crop in addition to deterioration of soil health. To maintain the productivity of groundnut it is important to avoid excess soil moisture loss through evaporation. Which can be achieved through mulching. Therefore, it is necessary to realize the need and importance of conservation and efficient utilization of water for production purpose through micro-irrigation technology and mulching in groundnut crop during *rabi* season.

A field experiment was conducted at Agronomy Farm, College of Agriculture, Dapoli during *rabi* season 2002-2003 in Split Plot Design. The soil was sandy clay loam in texture (sandy 25.28%, clay - 29.56%, loam - 44.62%) and slightly acidic in reaction (pH- 6.6) having moderate available nitrogen (325.81 kg/ha) low available phosphorus (12.69 kg/ha) and low potash (250.95 kg/ha). The moisture content at field capacity and permanent wilting point was 29.90% and 14.58% respectively. The crop was sown by hand dibbling at spacing 30 cm x 10 cm. The plot size was 4.8 m x 3.9 m. Recommended dose of fertilizers (50 kg N, 100 kg P_2O_5 and 50 kg K_2O/ha) was applied as basal dose. Sixteen treatment combinations was comprised with four main plot treatments of irrigation levels (100% P.E., 80% P.E., 60% P.E. and 40% P.E.) and mulches as sub plot treatment (no mulch, grass mulch, straw mulch and polythene mulch). Paddy straw and grass were spread @ 7 t/ha as a mulch. White polythene film (90 cm wide and 7 micron thickness) was used for mulching.

Irrigation level: Effect on yield contributing characters like total number of pods, number of developed pods and number of effective pegs/plant were highest and significantly superior with I_3 irrigation as compared to all other irrigation levels except I_2 irrigation level in number of effective pegs (Table 1). Data on pod yield showed that, dry pod yield (3618 kg/ha) which was on par was significantly more in I_3 treatment as compared to all other treatments except with I_2 irrigation level (3485 kg/ha). Similar trend also observed in kernel yield. Firake (2000) reported the similar response of groundnut to application of irrigation.

Effect of mulch treatments: Yield contributing characters *viz.*, number of pods, number of developed pods and number of effective pegs were significantly highest with polythene mulch as compared to all other mulch, except it was at par with straw mulch treatment in number of effective pegs/plant. Dry pod yield and kernel yield polythene mulch treatment recorded significant highest dry pod (3596 kg/ha) and kernel yields (2427 kg/ha) as compared to all other mulches except straw mulch which was on par with straw mulch (3409 and 2336 kg/ha respectively) Kathmale *et al.*, (2000) and Shinde *et al.*, (2002) also reported the similar response of polythene mulch in recording groundnut kernel and pod yield (kg/ha), which were significantly highest as compared to straw and no mulch treatments.

Water saving: Data from table 2 indicated that water saved to the extent of 17.27, 35.03, 52.79% by the irrigation level I_2, I_3 and I_4 respectively over the I_1 irrigation treatment. The seasonal water requirement of crop in I_1 was 47.18 ha/cm and in case of remaining irrigation levels it was 39.03, 30.65 and 22.27 ha/cm in treatment I_2, I_3 and I_4, respectively.

Field water use efficiency: The field water use efficiency was maximum in I_4 (120.7 kg/ha cm) followed by I_3, I_2 and I_4 *viz.* 63.0, 89.3 and 118 kg/ha cm.

Table 1 Effect of irrigation levels and mulch on yield of groundnut

Treatment	Total no of pods/plant	No. of developed pods/plant	No. of effective pegs/plant	Dry pod yield kg/ha	Kernel yield kg/ha
A) Irrigation Level					
I. –(100% of P.E.)	27	24	28	2983	2112
I_2 –(80% of P.E.)	30	26	32	3485	2392
I_3 –(60% of P.E.)	327	30	34	3618	2405
I_4 –(40% of P.E.)	27	22	26	2618	1846
SEm ±	0.3	0.7	0.7	105	68
CD (P = 0.05)	0.8	2.7	2.4	365	237
B) Mulch Treatment					
M_0 – No mulch	28	23	28	2707	1861
M_1 – Grass mulch	29	26	30	3062	2131
M_2 – Straw mulch	30	25	31	3409	2336
M_3 – Polythene mulch	30	27	32	3596	2427
SEm ±	0.3	0.6	0.5	80	68
CD (P = 0.05)	1.0	1.8	1.3	235	200

I = Irrigation level; M = mulch

Table 2 Details of irrigation water components

Treatment	Irrigation Water Applied (ha/cm)	Effective Rainfall (cm)	Seasonal Water Requirement (ha/cm)	Saving Over I_1 (%)	Yield (kg/ha)	F.W.U.E. (kg/ha/cm)
Irrigation Level						
I_1 –(100% of P.E.)	46.78	0.4	47.18	---	29.83	63.2
I_2 –(80% of P.E.)	38.63	0.4	39.08	17.27	39.85	89.3
I_3 –(60% of P.E.)	30.25	0.4	30.65	35.03	36.18	118
I_4 –(40% of P.E.)	21.87	0.4	22.27	52.79	26.88	120.7

I = Irrigation level

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Short communication

Evaluation of groundnut, *Arachis hypogaea* L. germplasm accessions for identification of resistant sources to stem and pod rot disease caused by *Sclerotium rolfsii*

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Stem and pod rot of groundnut caused by *Sclerotium rolfsii* (Sacc) inflicts 5-10% yield losses annually in India (Mehan *et al.*, 1995). The fungus is ubiquitous, non-target and most destructive soil inhabitant plant pathogen; the disease is widespread causing significant yield losses in Bolivia, China, Egypt, India, Taiwan, Thailand and United States of America. In India, the disease is more severe in Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, Orissa and Tamil Nadu (Krishnakanth *et al.*, 1999). Groundnut crop grown under assured rainfall and irrigated tacks in the post-rainy and summer season in India is often infected by the pathogen. Chemical and cultural practices have been the predominant means for the management of this disease (Porter *et al.*, 1982). Persistence of the pathogen in soil and wide host range often limits the effectiveness of chemical and cultural control of stem and pod rot disease (Csinos, 1984; Shew *et al.*, 1987). However, such cultural practices coupled with partially resistant cultivars can increase the efficiency of the disease management (Shew *et al.*, 1984). Non-random distribution of natural sclerotial inoculum in soils and unavailability of information on actual benefits of a stem and pod rot resistant cultivar, the benefits of genetic resistance is not known. However, genetic resistance, from an identified genuine source has been proposed to be the only effective way of mitigating this disease in an eco-friendly manner (Csinos, 1984). Therefore, evaluation of available accessions at Regional Research Station (RRS), Raichur was undertaken to identify potential resistance source.

A regional core collection (508) of groundnut accessions comprising the lines previously obtained from International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hyderabad advanced breeding lines and varieties released for general cultivation in the region were used for evaluation. Experiment was conducted at RRS, Raichur and Agricultural Research Station (ARS), Kawadimatti, which are located at a latitude of 16° 15' and latitude of 71° 25' E and 15° 45' N and longitude of 76° 52', respectively. Evaluation for the incidence of the disease was conducted in the stem and pod rot sick plots at both research stations during *kharif*, 2000, in an augmented plot design with two replications. All recommended package of practices for groundnut in the region were adopted. The disease incidence for each genotype was scored using ICRISAT scale for pod and stem rot incidence; 0%: immune; 0.1 to 10% : highly resistant; 10-20% : resistant; 20-50% : moderately susceptible; more than 50% : highly susceptible. An assessment of extent of damage due to disease was done by digging and inverting the affected plants. The reaction of the individual accession for infection and further damage was scored as per the ICRISAT scale. Data from RRS, Raichur and ARS, Kawadimatti was pooled to arrive at the final assessment of individual accession.

Number of accessions falling under different categories of disease scoring scale is presented in Table 1. It was clear from the results that none of the accessions among 508 exhibited immune reaction either at one or both locations of evaluation. However, a total of 339 accessions accounting for 61.86% recorded an infection less than 10 %, which were categorized as highly resistant (Table 2). One hundred fifty five genotypes (28.28%) of the total accessions fell under the category of resistant, recording an infection in the range of 10-20%. In the susceptible category, 9.67% of the accessions (53 accessions) grouped under moderately susceptible with an infection range of 20-50% whereas, only one genotype, R 8808, was found to be highly susceptible. An exhaustive screening conducted at ICRISAT and Marathwada Agricultural University, Parbani recorded an absence of immune reaction in a set of 859 accessions however accessions with minimal damage in the range of >1 to 10% were reported (Mehan *et al.*, 1995).

A sub-set of 50 accessions in the category of less than 10% infection, highly resistant category, were selected and further evaluated in the sick plot at RRS, Raichur.

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Table 1 Relative proportion of groundnut accessions falling in to different resistant groups

Resistance group	No. of accessions	Per cent disease range (%)	Per cent of total accessions
Immune	0	0	0.00
Highly resistant	>0-10	339	61.86
Moderately resistant	>10-20	155	28.28
Moderately susceptible	20-50	53	9.67
Highly susceptible	>50	1	0.002

Table 2 Identity of selected accessions showing highly resistant response to pod and stem rot disease

ICG No.	Botavar	Identity	Per cent disease
10707	HYB	TCG 1525	2.2
8274	VUL	NCAC 18019	2.3
13902	FST	SS 34	2.4
225	HYB	PI 269710 (NCAC **38)**	2.4
385	HYR	Haryanawadi	2.5
3048	HYB	ND 8-2	2.6
9561	FST	VRR 472	2.6
10174	FST	Tai son (Jewel Nut)	2.7
9501	VUL	RR 522 8090	2.8
6205	FST	PI 268559 (NCAC 10121)	2.8

HYR = Hypogaea runner; HYB = Hypogaea bunch
FST = Fastigiata; VUL = vulgaris
HR = Highly resistant MR = Moderately resistant
MS = Moderately susceptible HS = Highly susceptible

Artificial inoculation of *S. rolfsii,* a major causal agent of the disease, was done. The mycelial mat from 20 flasks each with 500 ml broth was pooled and further diluted to 20 liters using distilled water for drenching the stem region of the plant in the field. Three accessions belong to hypogaea bunch type (TCG 1525, P 1269710 [NCAC 38] and ND 8-2) one belongs to hypogaea runner (Haryanawadi), *four belong to fastigiata (*SS 34, VRR 472, Tai son (Jewel Nut) and P 1268559 (NCAC 10121) and two belong to vulgaria (NCAC 18019 and RR 5290) were highly resistant to stem and pod rot as per our evaluation. General elicitors of fungus such as oligo-N-acetygluconsamines *and oligogalacturonates are* known to impart resistance response in several plants. However, a number of species-specific elicitors are also known (Parker *et al.*, 1988). A glyco-protein derived from *S. rolfsii* fungus induces many defense reactions in plant species as elucidated *in vitro* cell culture experiments (Venkatachalam *et al.*, 1998). In general, the elicitor activity is viewed by its ability to binding to a specific cell surface-localized plant receptor that initiates a defense-related transduction cascade leading to resistant reaction. Irrespective of the mechanism underlying the resistance response and in the absence of an immune source for stem and pod rot disease the accessions reported in the present study would be useful in resistance breeding programme in groundnut.

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Short communication

Stability analysis in Indian mustard, *Brassica juncea* (L.) Czern and Coss genotypes for yield and its component traits

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Rapeseed-Mustard is a group of the important *rabi* oilseed crops of India. A specified genotype dose not exhibit the same phenotypic characteristics under all environments and different genotypes respond differently to a specified environment. This variation arising from the lack of correspondence between the genetic and non-genetic effects is known as the genotype x environment interaction. The stable performance of varieties under different environments with regard to seed yield has gained considerable significance in any varietal improvement programme. The present investigation was planned to generate information on Indian mustard genotypes for identifying high yielding and stable genotype(s) for cultivation under varied environments.

The experimental material comprised of eight promising genotypes of Indian mustard. These genotypes were tested in Split Plot Design with four dates of sowing (Oct.2 and 18, Nov.2 and 19, 2002) in main plots and genotypes in sub-plots in three replications at Main Castor-Mustard research station, SDAU, Sardarkrushinagar during *rabi* 2002-2003. A uniform fertilizer level of 37.5:50:00 NPK kg/ha and 200 kg gypsum/ha was applied as a basal, while 37.5 kg N/ha was applied as top dressing at the time of first irrigation. The crop was sown at a spacing of 45 cm x 15 cm. The crop received four irrigations during critical stages of crop growth. The other cultural practices and control for diseases and insect pests were performed as and when required. Each genotype was grown in plots of 5 rows, 5 m long and 45 cm apart. Data on 10 competitive plants of the each net plot (4.50 x 1.35 m^2, three rows) were recorded for eight characters. The oil content of the seeds was determined by Nuclear Magnetic Resonance (NMR). The stability analysis was carried out following Eberhart and Russell (1966).

The mean squares due to genotypes were significant for seed yield, length of main branch, branches/plant, siliquae/plant, length of siliqua, seeds/siliqua, oil content and harvest index when tested against pooled error indicating that genotypes were distinct for these attributes (Table 1). The mean squares due to genotype x environment (G x E) interactions were significant for seed yield, length of main branch, branches/plant and seeds/siliqua implying differential behaviour of genotypes under four different environments. The results are in agreement with those of Henry and Daulay (1988). Significant mean squares due to environment (linear) observed for all the characters suggested considerable differences among environments and their predominant effect. The linear component of G x E interaction was significant for seed yield, length of main branch, branches/plant and seeds/siliqua suggesting that the genotypes differed for their linear response to environments. Similar results were reported for seed yield/plant by Sarma and Roy (1993). The mean squares for pooled deviation were non significant for all the characters. Thus, the performance of genotypes with respect to these characters was entirely predictable in nature.

The genotype SKM 2026 had the highest seed yield (2041kg/ha), unit regression (bi=0.97) and the lowest deviation from regression (Table 2). Thus this genotype appears to have average stability and suitability for all the dates of sowing. Kranti possessing higher seed yield, bi less than unity and non significant S^2di was found to have its better adaptability in poor environment for this trait. Non-significant S^2di, above average response (bi>1) and considerably high mean performance of NM 919 for seed yield, length of main branch, length of siliqua and harvest index indicated its superior adaptability for favorable environment (October 18) for these traits. NPJ 82 has less than unity (bi<1) regression value, non significant S^2di and high mean performance for length of main branch, branches/plant, siliquae/plant and siliqua length, appeared to have superior adaptability to poor environment (November 19th and October 2nd) for these traits. The variety BIO 902 exhibited average response and the highest mean performance for number of branches/plant, but its performance was unpredictable as it showed significant S^2di (151.03**).

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

Source of variation	d.f.	Seed yield (kg/ha)	Length of main branch	Branches/ plant	Siliquae/ plant	Siliqua length	Seeds/ siliqua	Oil content (%)	Harvest index (%)
Replication within Environment	8	41.815	9.012	113.522	2753.69	0.022	0.182	3.275**	5.864
Genotypes	7	87.243**	78.089**	131.642**	5730.28*	0.501**	1.382**	5.133**	14.506**
Env. + (Genotypes*Environment)	24	55..967	59.940	200.699	7874.18	0.140	1.109	2.196*	4.999
Environments	3	278.189**	254.031**	1040.499**	41826.40**	0.201	3.521**	12.193**	9.782
Genotypes*Environment	21	23.045**	32.212**	80.728**	3023.86	0.131	0.765**	0.768	4.316
Environments (Linear)	1	836.214**	762.093**	3121.497*	125479.20**	0.603*	10.564*	36.578**	29.347*
Genotypes*Environment (Linear)	7	27.984**	58.352*	119.298**	3473.02	0.059	1.097*	0.443	4.312
Pooled Deviation	16	18.107	16.750	53.762	2449.37	0.147	0.523	0.814	3.778
Pooled error	56	04.938	9.292	25.663	2727.40	0.070	0.279	0.510	2.743

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

SKM 2026 and NPJ 82 showed stable performance for siliquae/plant and oil content, respectively. The genotype DHR 991 and NPJ 82 with more seeds/siliqua and above average response showed predictable performance under favorable environments (October 18th). It has revealed that, genotype KM 2026 for average environment, NM 919 for favorable environment (October 18th) and Kranti for poor environment (November 19th) were found high yielding and can further be exploited in future breeding programme.

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Short communication

Response of mustard, *Brassica juncea* (L.) Czern and Coss. varieties to different sowing times under semi arid conditions of Rajasthan

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Mustard (*Brassica juncea* (L.) Czern and Coss is one of the most important edible oilseed crops especially in the North India. Despite having the maximum area (14.03 l. ha) and production (13.03 l. tonnes), its productivity in Rajasthan state is very low (929 kg/ha) due to biotic and abiotic stresses (Anonymous, 2002b). The final yield of a crop mainly depends on the genetic constitution and the weather conditions which it encounters during its growth and development. Early sown mustard crop suffers due to higher temperature and moisture stress while, late sown crop does not get sufficient time to produce efficient source for assimilates and it is also heavily invaded by pests mainly the aphids. Hence, sowing of the crop at proper time is an important non-monitory input for enhancing crop productivity (Shastry and Kumar, 1989). The present study was, therefore, undertaken to find out suitable cultivar and optimum time of sowing under semi-arid eastern plain zone of Rajasthan.

A field study was conducted during *rabi* season of 2001-02 at S.K.N. College of Agriculture, Jobner, Rajasthan (26° 51 N latitude, 75° 2' E longitude and 427 m A.S.L.). Soil of the experimental field was loamy sand in texture, slightly alkaline in reaction (pH 7.9), low in available nitrogen (125.9 kg/ ha) and medium in available phosphorus (17.3 kg/ha) with organic carbon 0.21%. The treatments comprised of four dates of sowing (25th Sept., 10th Oct., 24th Oct. and 7th Nov.) and six cultivars (SKM 9816, RH 9623, Bio 902, Kranti, SAL 2 and Urvashi) assigned to main and sub plots, respectively, in split plot design and replicated thrice. A uniform dose of 30 kg/ha of each nitrogen and phosphorus was applied at the time of sowing. Remaining dose of 30 kg/ha nitrogen was top dressed at the time of first irrigation. The crop was sown at a row spacing of 30 cm using 5 kg seed/ha after applying presowing irrigation. Two irrigations were applied at the time of flowering and pod development stages. A prophylactic spray using phosphamidon 0.025% was done against aphids during pod filling stage. Observations on growth and yield attributes and seed yield were recorded at the time of harvest and data were analysed statistically.

It is apparent from the data that growth and yield attributes of mustard were significantly influenced by different dates of sowing (Table 1). These parameters *viz.*, plant height, primary and secondary branches/plant, number of siliquae/plant and seeds/siliqua and test weight attained their significantly highest values when the crop was sown on 10th October. The performance of the crop in reference to these attributes was noted poor when sowing was done after first fortnight of October. Improvement in these characters can be better explained by the fact that the crop sown during second week of October received optimum environmental conditions (min. and max. temperature, 15.5 and 33.5 °C) required for better crop growth and development. Whereas, delay in sowing up to 24th Oct. and 7th Nov., caused slow germination due to lower temperatures (min. temperature, 13.2 and 8.1°C) and thus could not provide the sufficient time to complete the vegetative phase of the crop. Hence, the crop could not accumulate sufficient dry matter and photosynthesizing area (source) that could have been very useful in partitioning of the assimilates towards sink. These results are in accordance with those of Singh and Singh (1991) and Yadav and Yadav (1997).

Mustard sown on 10th October produced the maximum seed yield of 1718 kg/ha, though, it remained at par with 25th September (Table 2). Delay in sowing after 10th October significantly declined the seed yield with a minimum of 1101 kg/ha obtained when the crop was sown on 7th November. This improvement in seed yield can mainly be attributed to the corresponding improvement in crop growth and yield parameters of the crop. The results are in close conformity with those reported by Punia and Thakral (2000) and Singh *et al.* (2001).

The varieties showed significant variation in growth and yield parameters of mustard (Table 1). Kranti recorded the maximum values of these attributes among all the varieties. Bio 902 and SKM 9816 remaining at par with Kranti also brought about significant improvement in these characters. Similarly, Kranti with a seed yield of 1640 kg/ha performed significantly superior than SAL 2 and Urvashi and accounted 12.9 and 26.9% increase over these varieties, respectively (Table 1). Bio 902, SKM 9816 and RH 9623 corresponding with seed yields of 1562, 1502 and 1491 kg/ha, also performed statistically at par to Kranti and thus proved next superior varieties. Significant variation in seed yield can be mainly due to the differences in their genetic constitution. Significant improvement in yield attributes might have also increased the seed yield of these varieties. These varieties also performed better at Kanpur, Pantnagar and Akola locations (Anonymous, 2002a).

Interactive effect of date of sowing with varieties was also found to significantly influence the seed yield of mustard (Table 2). The maximum seed yield of 1970 kg/ha was obtained when Bio 902 was sown on 10[th] October. It was closely followed by variety SKM 9816 sown on the same time. Kranti sown on 25th September producing a seed yield of 1886 kg/ha also proved at par to the above combinations. The lowest seed yield (890 kg/ha) was obtained when SKM 9816 was sown on 7[th] October.

Mustard sown on 10[th] October fetched the maximum net returns and thus resulted additional income over 25[th] September, 24[th] October and 7[th] November dates of sowing, respectively. Whereas among varieties, increasing the net returns to the extent of 5.0, 9.2, 10.0, 12.9 and 26.9%, respectively, over Bio 902, SKM 9816, RH 9623, SAL 2 and Urvashi, Kranti performed the best. The higher net returns can be assigned to the corresponding seed yields that were also higher under these superior treatments.

Table 1 Effect of date of sowing and varieties on growth and yield attributes of mustard

Treatment	Plant height (cm)	Branches/plant		Siliquae/ plant	Seeds/ siliqua	Test weight (g)	Seed yield (kg/ha)	Net returns (Rs/ha)
		Primary	Secondary					
Date of sowing								
25.09.2001	167	4	4	148	13	6.1	1659	17585
10.10.2001	169	4	4	152	14	6.5	1718	18352
24.10.2001	150	4	4	137	12	5.9	1481	15271
07.11.2001	131	3	3	119	9	5.0	1101	10331
CD (P=0.05)	8.0	0.4	0.6	9.4	1.1	0.6	190	-
Variety								
SKM 9816	158	3.8	3.6	140	12.5	5.7	1502	15544
RH 9623	150	3.8	3.8	137	12.1	5.8	1491	15401
Bio 902	158	4.0	3.8	144	12.4	6.2	1562	16324
Kranti	163	4.1	4.1	149	12.8	6.4	1640	17338
SAL 2	153	3.6	3.5	135	11.5	5.6	1453	14907
Urvashi	139	3.5	3.3	128	10.6	5.6	1292	12814
CD (P=0.05)	10.7	0.4	0.4	10.1	1.1	0.6	156	-

Table 2 Combined effect of date of sowing and varieties on seed yield of mustard (kg/ha)

Treatment	Variety					
	SKM 9816	RH 9623	Bio 902	Kranti	SAL	Urvashi
Date of sowing						
25.09.2001	1770	1853	1720	1886	1370	1363
10.10.2001	1930	1653	1970	1820	1563	1373
24.10.2001	1417	1397	1367	1477	1767	1463
07.11.2001	890	1060	1190	1377	1110	977
CD (P=0.05)	3.11					

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Short communication

Effect of sowing method and time of first irrigation on growth and yield of *Brassica campestris* sub sp. *oleifera* var. toria

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Toria is grown as *ziad rabi* crop followed by late sown wheat or spring sunflower under irrigated conditions in Punjab. Water stress at early stage in toria crop restricts the build-up of infrastructure framework, however, at the later stage adversely affects seed filling rate and sink capacity (Mahal, 1990). Since irrigation water is one of the costlier inputs, its economic and efficient utilization becomes quite imperative. Besides, method of sowing play an important role not only in optimizing production/unit area but also facilitates the interculture operations, light penetration and better root growth which helps in efficient use of applied water. Keeping in view the above facts, a study was undertaken to get precise information on these aspects.

A field experiment was conducted at the Research Farm of Regional Station, Gurdaspur, Punjab Agricultural University, Ludhiana during the winter season of 2000-01 to study the effect of sowing methods and first irrigation on growth and yield of toria (*Brassica campestris* sub sp. *oleifera* var. toria). The treatments comprised four sowing methods *viz.*, flat sowing (normal method), flat wet method (broadcast seeds in standing water), bed sowing (67.5 cm and two rows of toria/bed), corrugation method (cultivation followed by planking) and three times of irrigation, *viz.*, no irrigation, first irrigation four weeks after sowing (4 WAS) and first irrigation six weeks after sowing (6 WAS). Total 12 treatments were laid out in a Randomized Block Design, replicated thrice, 62.5 kg N/ha and 20 kg P_2O_5/ha were applied as recommended by Punjab Agricultural University, Ludhiana. The soil was silty clay-loam, having pH 6.9, available N, P_2O_5, K_2O, 195, 26, 192 kg/ha, respectively. The crop was sown on 16th September, 2000 by applying heavy pre-sowing irrigation and harvested on December 10, 2000. The total rainfall during the crop season was 24.7 cm. The minimum and maximum temperature ranged from 7.3°C and 39.5°C during the experiment.

The plant height of toria was significantly more in bed sowing method (124 cm) followed by flat sowing method (112 cm), corrugation method (109 cm) and flat wet method (91 cm), respectively (Table 1). The plant attained significantly more height when first irrigation was applied 4 weeks after sowing. However, the height was statistically same when no irrigation was applied as well as first irrigation was applied 6 weeks after sowing. Seed yield of toria was significantly more under bed sowing method (1020 kg/ha) followed by flat sowing (950 kg/ha), corrugation (750 kg/ha) and flat wet method (530 kg/ha), respectively (Table 2). It was observed that under flat and bed sowing methods, seed yield increased upto 92.4 and 79.2% over the flat wet, 36.0 and 26.6% over corrugation method, respectively. The seed yield was lowest in case of flat wet method because of lesser plant height, primary branches and 1000 seed weight in comparison to all other methods.

Application of irrigation at 4 weeks after sowing resulted in highest seed yield (1060 kg/ha) as compared to 6 weeks after sowing and control plot due to vigorous growth and more number of branches/plant. These results are in conformity with Narang *et al.* (1993), who reported that irrigation at four weeks after sowing make the early build up of plant infrastructure, hence, resulting in more seed yield.

Table 1 **Effect of different treatments on the growth and yield attributes of toria**

Treatment	Plant height (cm)	Branches / plant	Seeds/ pod	1000-seed weight (g)
Method of sowing				
Flat sowing	112	6.4	23	2.4
Flat wet method	91	5.3	21	2.2
Bed sowing	124	9.6	25	2.4
Corrugation method	109	5.9	23	2.4
CD (P=0.05)	7.6	0.3	2.1	0.09
Time of first irrigation				
No irrigation	104	5.4	22	2.3
First irrigation 4 weeks after sowing	116	8.6	24	2.4
First irrigation 6 weeks after sowing	108	6.4	23	2.3
CD (P=0.05)	6.6	0.3	1.8	0.09

Table 2 **Effect of different treatments on the seed yield (kg/ha) of toria**

Method of sowing	Seed yield (kg/ha) Time of first irrigation			Mean
	No irrigation	First irrigation 4 weeks after sowing	First irrigation 6 weeks after sowing	
Flat sowing	800	1350	1390	1180
Flat wet method	520	530	540	530
Bed sowing	1110	1340	590	1020
Corrugation method	570	1040	630	750
Mean	750	1060	790	

Seed yield (Mean) : CD (P=0.05) = 30
Interaction (Method of sowing x Time of first irrigation : CD (P=0.05) = 50

Interaction effect of irrigation x method of sowing revealed that under flat sowing, the seed yield was statistically same with first irrigation at 4 weeks or at 6 weeks after sowing but significantly more in the absence of irrigation. Under flat bed method, there was no need of irrigation, as the seed yield was same under all irrigation treatments. Under bed sowing and corrugation method, seed yield increased by 127.1 and 65% when first irrigation was applied at 4 weeks after sowing as compared to 6 weeks after sowing due to reduction of branches/plant at 6 weeks after sowing.

It was interesting to note that, when we compared the seed yield in the absence of irrigation, bed sowing method was found more suitable followed by flat sowing, flat wet and corrugation methods. In case of first irrigation at 4 weeks after sowing, flat and bed sowing methods were found more suitable than corrugation and flat wet method. In case of first irrigation at 6 weeks after sowing, only flat sowing method was found suitable than any other method.

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Short communication

Assessment of avoidable yield losses due to white rust in Indian mustard, *Brassica juncea* (L.) Czern & Coss

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Indian mustard [*Brassica juncea* (L.) Czern. and Coss] is one of the most important oilseed crops in India. Among the various fungal diseases of this crop, white rust caused by *Albugo candida* (Pers. Ex Hook.) O.Kuntze is most widely prevalent in different parts of the country. The epidemic development of white rust is dependent upon many factors, *viz.*, aggressiveness of pathogenic race, amount of initial inoculum, time of first appearance of the disease and prevailing weather conditions (Singh *et al.*, 2003). These factors determine the intensity of disease and associated yield loss.

Yield losses up to 27.2% and 89.8% due to leaf and staghead phase of white rust, respectively (Saharan *et al.*, 1984; Lakra and Saharan, 1989) and 17-32% due to its mixed infection with downy mildew have been reported (Bains and Jhooty, 1979). White rust appears every year on the mustard crop in the mid hill conditions of Himachal Pradesh. However, no information is available about the yield losses due to the disease in mid-hill Himachal Pradesh. The present studies were conducted to estimate the extent of avoidable yield losses due to white rust in different recommended varieties of Indian mustard under natural epiphytotic conditions.

A field experiment was conducted for two years during post rainy (*rabi*) seasons of 1998-99 and 1999-2000 at the experimental farm of Shivalik Agricultural Research and Extension Centre, Kangra, Himachal Pradesh. Five varieties of Indian mustard namely Varuna, Pusa Bold, RCC-4, Kranti and RL-1359 were evaluated by keeping the plots protected by three sprays of Ridomil MZ (0.25%) on 60, 80 and 100 days after sowing and maintaining unprotected plots. The experiment was laid out in Randomized Block Design keeping a plot size of 3.0m x 2.4 m in three replications. Recommended agronomic practices for cultivation of mustard in Himachal Pradesh were followed (Anonymous, 1994). Sowing was done on November 4, 1998 and November 6, 1999.

Disease severity of white rust on leaves was recorded in each treatment on 0-5 scale (Anonymous, 1988) by observing 25 leaves from the middle portion of the randomly selected plants. Staghead infection was assessed by counting the infected and healthy inflorescences per plant. Percent disease intensity (PDI) was calculated using the formula of Mc Kinney (1923). Seed yield was recorded after the harvest of the crop.

Disease could be checked in the protected plots by three sprays of Ridomil MZ. Among the unprotected treatments white rust infection on leaves was highest (22.7%) in variety Pusa Bold during 1998-1999, whereas, highest disease (25.3%) was recorded in variety Kranti during 1999-2000 (Table 1).

Table 1 Assessment of avoidable yield losses due to white rust in different varieties of Indian mustard

Treatment	Disease severity (%)						Seed yield (kg/ha)			Yield loss (%)		
	White rust (leaves)			Stag head								
	1998-99	1999-2000	Mean	1998-99	1999-2000	Mean	1998-99	1999-2000	Mean	1998-99	1999-2000	Mean
Varuna (P)	4.3	1.3	2.8	0.2	0.2	0.2	1416	1481	1449	14.3	20.9	17.6
Varuna (UP)	19.2	21.3	20.3	5.6	8.8	7.2	1213	1172	1193			
Pusa Bold (P)	4.5	1.9	3.2	0.5	0.3	0.4	1125	1232	1179	24.7	27.1	25.9
Pusa Bold (UP)	22.7	21.1	21.9	9.2	11.4	10.3	847	898	873			
RCC-4 (P)	3.5	0.8	2.2	0.5	0.3	0.4	1491	1415	1453	15.0	[illegible]	16.4
RCC-4 (UP)	20.8	23.7	22.3	7.0	8.7	7.9	1268	1164	1216			
Kranti (P)	3.2	1.1	2.2	0.6	0.3	0.5	1398	1366	1382	14.2	19.2	16.7
Kranti (UP)	20.4	25.3	22.9	7.0	9.6	8.3	1199	1104	1152			
RL-1359 (P)	3.7	0.8	2.3	0.4	0.3	0.4	1468	1457	1463	16.1	20.4	18.3
RL-1359 (UP)	20.5	22.1	21.3	7.9	10.9	9.4	1232	1160	1196			
CD (P=0.05)	2.5	2.4	-	1.1	1.3	-	116	182	-	-	-	

P = Protected; UP = Unprotected

However no remarkable differences were observed in the disease intensity on leaves among different varieties. Highest staghead infection was observed in variety Pusa Bold *during both the years. Average staghead incidence* was also highest in variety Pusa Bold (10.3%) followed by RL-1359 (9.4%), Kranti (8.3%), RCC-4 (7.9%) and Varuna (7.2%).

Seed yield was highest in variety RCC-4 under protected as well as unprotected conditions during 1998-99, whereas highest yield was recorded in variety Varuna under both the conditions during 1999-2000. However, no significant differences in yield was observed among various varieties except Pusa Bold, which recorded significantly lower yield as compared to other varieties both under protected as well as unprotected conditions during both the years.

Difference in yield losses was observed among various varieties. Pusa bold recorded highest yield loss of 24.7% and 27.1% during 1998-99 and 1999-2000, respectively. This may be because of the higher floral infection of white rust in case of Pusa Bold during both the seasons. Meena *et al.* (2002) reported each percent white rust and staghead formation causes reduction in seed yield of about 82 kg and 22 kg/ha, respectively. Since there was no significant difference in the percent disease intensity on leaves among the varieties, the difference in yield loss may be because of differences in staghead intensity among the varieties. On the basis of average of two years data, yield losses due to disease were maximum in Pusa Bold (25.9%) followed by RL-1359 (18.3%), Varuna (17.6%), Kranti (16.7%) and RCC-4 (16.4%). Saharan *et al.* (1984) also observed differences in yield losses due to white rust among different varieties of Indian mustard. They reported yield loss of 23.0-54.5% in variety RH-30 and 27.4-62.7% in variety Prakash under late sown conditions. From our studies, it seems, varieties RCC-4, Kranti and Varuna are tolerant to white rust disease. These yield losses due to white rust can be avoided if appropriate control measures are measures are adopted by the farmers. Otherwise farmers can choose cultivate tolerant varieties like RCC-4, Kranti or Varuna in the mid hill conditions of Himachal Pradesh.

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Short communication

Identification and characterisation of drought tolerant genotypes of Indian mustard, *Brassica juncea* (L.) Czern and Coss.

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Average productivity (968 kg/ha) of rapeseed-mustard crops in India is only 64.5% of the world's average (Anonymous, 2000). Nearly, 42% of the rapeseed-mustard area in rainfed, which could be the major reason for such low productivity because drought stress is hazardous to crop production. Drought is a complex phenomenon involving soil-plant-atmosphere continuum. Genetic enhancement of drought tolerance of the cultivars *per se* is foremost for increasing rapeseed-mustard production under drought prone/rainfed areas. Breeding drought tolerant varieties would require identification of appropriate donors, their utilization in hybridization and selection for the trait in segregating generations. Kumar *et al.* (1987); Sharma and Kumar (1989) and Wani and Srivastava (1989) reported genotypic variation in the response to water deficit in *Brassica* species. Reduction in number of pods/plant, seeds/pod and seed size under water stress condition has been reported in Indian mustard by Singh and Singh (1991) and Singh *et al.* (2002). The present investigation is an attempt to evaluate mustard germplasm accessions for seed yield and its components under moisture stress environment to identify suitable donors for utilization in the breeding programme for enhancing level of tolerance of Indian mustard cultivars which suit better to the drought prone areas.

Forty-nine accessions of Indian mustard were grown at two locations, *viz.*, NRCRM, Bharatpur, Rajasthan (Location I) and S.K.N. College of Agriculture, Jobner, Rajasthan (Location II), to study their performance under rainfed condition with 4 checks, Varuna, PCR 7, RN 393 and RH 819 in Augmented Block Design (Federer, 1956) during *rabi* season of 1999-2000. Each entry was grown in 2 rows of 3.5 m length. The plant spacing were 30 and 10 cm, respectively, between rows and between plants within a row. Soil moisture content at 3 (15, 30 and 60 cm) and 2 (30 and 60 cm) depths was measured at NRCRM and Jobner locations, respectively from sowing till harvest. Soil samples were taken with the help of augur. The weight of fresh soil was recorded using electronic balance, dried in oven at 105°C till constant weight was obtained and again weighed. The field capacity was 25%. Organic carbon in the soil was 0.5, 0.38 and 0.44%, at 15, 30 and 60 cm depth, respectively, at NRCRM. The pH value and electrical conductivity of soil were 7.8 and 0.48 milli Simen (mS), respectively. Fertilizer was applied at 40 kg N and 20 kg P_2O_5/ha at the time of sowing at both the locations. For aphid control oxydematon-methyl 25 SE was sprayed twice at an interval of 15 days. The weekly minimum and maximum temperature (°C), precipitation and minimum and maximum relative humidity (%) were recorded. Observations were recorded on randomly taken 5 competitive plants of each entry for plant height (cm), primary branches/plant, secondary branches/plant, main shoot length (cm), siliqua/main shoot, seeds/siliqua, siliqua length (cm), 1000-seed weight, yield/plant (g), biological yield/plant (g) and harvest index (%). Days to initial, 50% flowering and maturity were recorded on the row basis. Protein content (%) and oil content (%) were recorded on bulk seeds of five selected plants using Near Infra Red Spectroscopy (NIR). The critical difference between adjusted variety means against check means (AVAC) was used to compare different accessions against means of respective best check for different characters.

Weather: The weekly mean maximum temperature ranged from 17.1 to 36.8°C being maximum at the time of maturity. Likewise, the weekly minimum temperature ranged from 4.7 to 14.9°C whereas it was the lowest during February, 2000. The weekly minimum relative humidity (RH %) ranged from 9.3 at maturity (27th March - 2nd April, 2000) to 77.4% (3-9 Jan., 2000). The maximum RH varied from 68.3 at maturity (April, 2000) to 99% (January , 2000). The total precipitation occurred during crop season was 5.6 mm in 2 days during first fortnight of March at the NRCRM.

Pattern of soil moisture content: Soil moisture content decreased consistently and reduced from 14.8 to 4.2, 16.3 to 5.9 and 17.3 to 4.9% at 15, 30 and 60 cm soil depth from 26 days after seeding to siliqua formation (110 days after sowing). Soil moisture content was higher with the increased soil depth (Fig. 1). At Jobner soil moisture content decreased from 12.5 to 4.2 and 12.5 to 6.9% at 30 and 60 cm soil depth from sowing to maturity (Fig. 1).

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Analysis of variance: the blocks differed significantly for all the characters except for 1000-seed weight, seeds/siliqua, yield/plant and oil content at location II and days to initial flowering, days to maturity, primary branches/plant, seeds/siliqua and oil content at location I. The checks were significantly different for all the characters except for days to maturity, seeds/siliqua, siliqua length and oil content at location II; for days to maturity at location I. Accessions were also different for all the characters except for oil content at location II and primary branches/plant and seeds/siliqua at location I.

Performance of accessions: RH 819 was the best check for days to initial flowering at location I and two accessions, JMG 9601 and IS 1787 showed significantly early flowering initiation and 50% flowering. The checks, RN 393 and Varuna were the earliest to mature at location I and location II, respectively. Accessions, EC 347854, and JMG 9601 matured significantly earlier than the best check at location I. At location II, none of the accessions showed significantly early maturity over the best check (Table 1). Varuna and RH 819 were the best check for plant height at location I and location II, respectively. Accessions IS 1787 (149.0 cm) and PSR 20 (61.1 cm) had significantly shorter height than their respective best checks at location I and location II, respectively (Table 2).

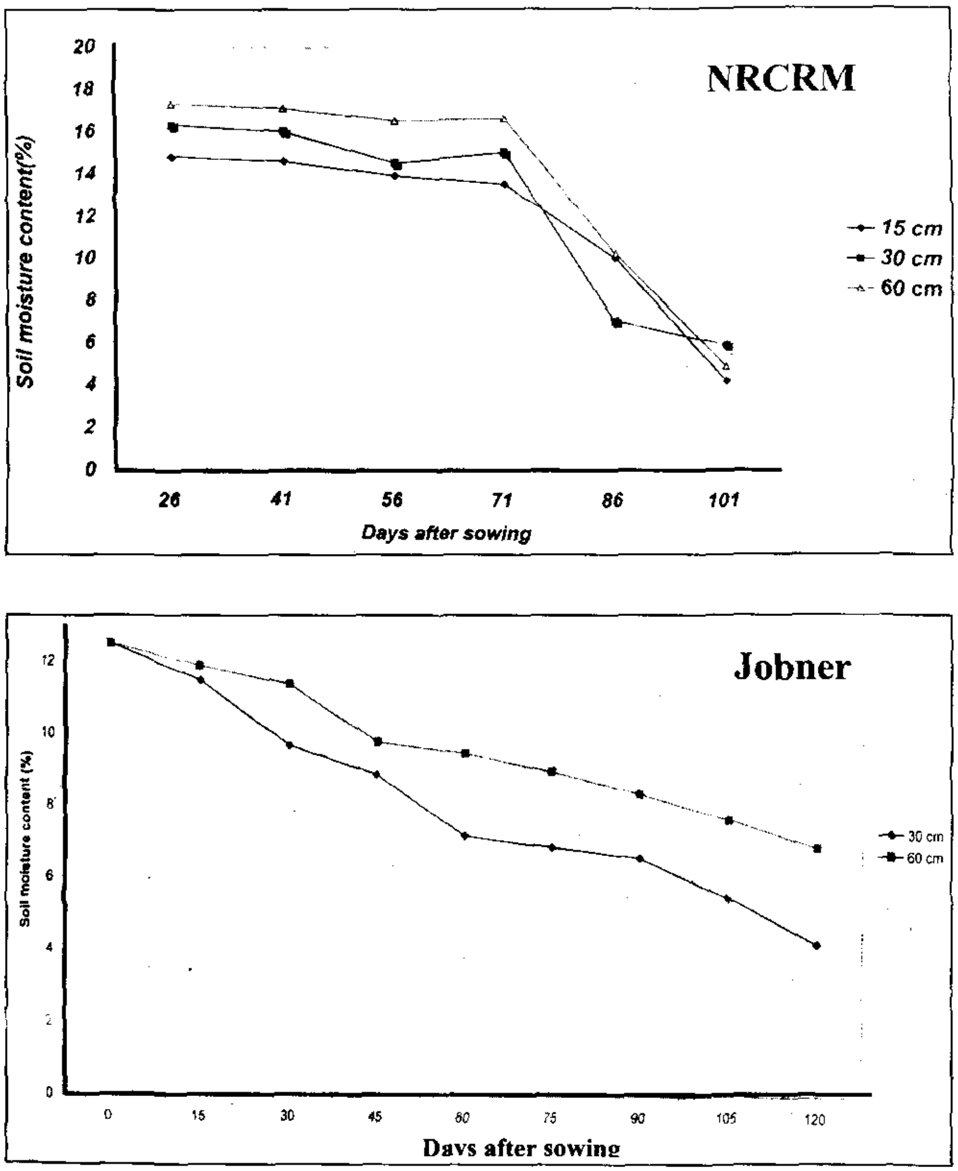

Fig. 1 Soil moisture content (%) at different crop stages under rainfed conditions

Table 1 Best check and best accession of Indian mustard at NRCRM (location I) and SKN College, Jobner (*location II*)

Character	Best check		Best accession	
	NRCRM (Location I)	Jobner (Location II)	NRCRM (Location I)	Jobner (Location II)
Days to initial flowering	RH 819 (59 days)	Nil	JGM 9601, IS 1787	NA
Days to 50% flowering	Varuna (62 days)	Nil	JGM 9601, IS 1787	NA
Days to maturity	Varuna (128 days)	Varuna (120 days)	EC 347854, JGM 9601	-
Plant height (cm)	Varuna (176.2)	RH 819 (95.6)	IS 1787	PSR 20
Primary branches/plant	RN 393 (5.1)	PCR (3.5)	-	IS 1787, DLM 58
Secondary branches/plant	-	RH 819 (8.3)	-	-
1000-seed weight *(g)*	Varuna (5.6)	Varuna (3.7)	PRO 9501	RC 53, PRO 9702, RC 26, RC 1446, DIR 673, RC 5, JMMWR 941
Main shoot length (cm)	Varuna (77)	-	-	NA
Siliqua/main shoot	PCR 7 (43.3)	Nil	**MDOC 96, PSR 20, B 431**	NA
Siliqua/plant	-	RH 819 (108.0)	-	IS 1787
Seeds/siliqua	PCR 7 (13.4)	*Varuna* (16.5)	-	-
Siliqua length (cm)	PCR 7 (5.2)	PCR 7 (3.8)	**-DIR 673**	RC 203, EC 347852
Yield/plant (g)	PCR 7 (12.2)	Varuna (5.8)	-	IS 1787, RC 53, PRO 9702
Biological yield/plant **(g)**	PCR 7 (59.1)	RN 393 (27.3)	-	IS 1787, PRO 9702, JMMWR 941
Harvest index (%)	RN 393 (20.0)	RH 819 (23.2)	RH 815, PSR 20, JMG 109	EC 347854, EC 86745, BE 3121, **RJ** 15, RC 5, JMG 181
Protein content (%)	RH 819 (20.9)	RN 393 (22.9)	IS 1787, UUR 90, JMG 117	-
Oil content (%)	RN 393 (40.5)	RH 819 (40.2)	Nil	Nil

NA : Data not recorded

Table 2 Characteristics of promising accessions having better performance at NRCRM (I) and SKN College, Jobner (II) under rainfed conditions

Accession	Maturity (days)		*Primary branches/* plant		1000-seed weight (g)		Seeds/ siliqua		Siliqua *length* (cm)		Seed yield/ *plant* (g)		Harvest *index* (%)		Oil *content* (%)		Protein content (%)	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
RC 53	128	122	3.0	3.9	5.5	4.3	11.9	12.4	4.4	3.4	9.0	7.1	19.3	29.2	39.1	39.7	21.0	23.5
PSR 20	128	123	5.5	3.1	4.2	2.4	13.0	11.4	4.9	2.8	20.6	1.9	3.1	12.1	41.6	40.0	21.0	23.8
IS 1787	127	123	3.9	5.4	5.2	3.9	12.8	13.6	5.4	4.0	10.9	8.6	15.9	30.9	38.5	39.9	23.2	21.6
DIR 673	129	122	3.6	2.4	6.2	4.3	11.5	11.6	6.4	3.8	8.7	4.6	11.0	22.8	41.6	39.4	19.4	22.5
RC 5	127	123	4.4	3.4	5.2	4.7	13.1	12.8	5.9	3.9	11.0	2.8	11.4	34.0	38.9	40.1	20.1	22.3
EC 347852	130	124	5.1	2.2	3.9	3.3	12.7	11.6	5.4	5.5	6.4	2.7	8.3	24.4	43.3	39.0	20.7	23.3
PRO 9702	130	121	5.0	2.9	5.7	4.5	11.8	14.1	4.9	3.7	10.8	7.1	22.2	26.4	38.1	40.0	19.6	22.2
BE 3121	127	124	5.5	4.2	4.2	2.4	13.0	11.4	4.9	3.1	6.6	5.6	5.8	32.5	38.7	39.8	20.9	23.4
JMMWR 941	126	125	5.1	3.0	5.4	4.4	12.0	13.4	5.0	3.5	8.5	5.6	26.1	19.7	38.1	39.6	21.1	22.3
RC 1446	129	123	3.3	3.2	6.4	4.8	10.7	11.4	5.7	3.9	9.0	5.4	14.2	27.9	38.1	40.1	19.8	22.0
PCR 7	127	118	7.4	2.7	6.5	4.0	16.1	15.0	6.3	4.6	23.6	5.4	27.3	30.3	42.0	41.9	21.5	24.3
Varuna	127	118	6.4	2.7	6.9	4.1	14.5	16.5	6.0	4.5	19.9	5.8	26.6	30.6	41.6	41.9	21.2	23.7
RN 393	126	119	8.0	2.9	5.7	3.7	16.0	16.2	6.2	4.6	22.2	5.6	28.6	29.2	43.6	41.9	22.2	24.5
RH 819	127	118	7.5	2.7	6.4	4.0	15.2	16.1	6.3	4.5	20.0	5.3	26.6	31.3	42.4	42.6	22.3	24.4

None of the accessions showed significantly higher number of primary branches/plant over the best check at location I. Means of checks for 1000-seed weight ranged from 4.4 - 5.6 g and 3.3 - 3.7 g at location I and location II, respectively. At location I, accession PRO 9501 (7.1 g) showed significantly higher seed weight over the best check, Varuna (5.6 g) while accessions DIR 673 (4.3 g), RC 53 (4.3 g), JMMWR 941 (4.4 g), PRO 9702 (4.5 g), RC 5 (4.7 g), RC 1446 (4.8 g) and RC 26 (4.9 g) showed significantly higher seed weight at Jobner over the best check, Varuna (3.7 g).

None of the accessions showed significantly higher main shoot length over the best check at location I (Table 1). Accessions B 43 (59.9 cm), PSR 20 (55.2 cm) and MDOC 96 (54.7 cm), showed significantly higher siliquae/main shoot over the best check (Table 1). This observation was recorded as siliqua/plant at location II, IS 1787 showed significantly higher siliqua/plant over the best check. Accession, DIR 673 (6.4 cm) had significantly longer siliqua over all the checks at location I, whereas, at location II accessions RC 203 and EC 347852 showed significantly higher siliqua length over the best check.

None of the accessions showed significantly superior yield/plant over the best check at location I, while, IS 1787, RC 53 and PR 9702 significantly out-yielded the best check at location II (Table 1). None of the accessions was significantly superior for biological yield/plant over any check at location I but at location II, accessions, IS 1787, PRO 9702 and JMMWR 941 had significantly superior biological yield over the best check. Accessions RH 815 (39.7%), JMG 109 (35.2%) and PSR 20 (31.0%), expressed significantly higher harvest index over the best check at location I (Table 1) whereas, at location II, accessions, EC 347854, EC 86745, BE 3121, RJ 15, RC 5 and JMG 181 revealed significantly higher harvest index over the best check. Accessions, IS 1787 (23.2%), UUR 90 (22.7%) and JMG 117 (22.3%) expressed significantly higher protein content over the best check at location I.

During flowering and siliqua formation stages many accession at location II showed excellent performance and on the basis of phenotypic expression, accessions CSR 134, CSR 313, MDOC 96, B 380, EC 347852, BE 3121, MDOC 76 and RC 48 were ranked first and accession JMG 117, PCR 7, Varuna, CSR 895, Bio 55-23, B 431 and DIR 673 ranked second. But on the basis of yield/plant these accessions did not show significant superiority over any check except accession BE 3121 and Varuna. Wani and Srivastava (1989) also reported RH 30 and Varuna of Indian mustard to be drought tolerant. Based on the performance at two locations, promising accessions (PSR 20, IS 1787, DIR 673, EC 347854, PRO 9702, JMMWR 941, UUR 90, MDOC 96 and PRO 9501) showing better performance than the checks for various traits have been identified and characterized (Table 2) so that they would be effectively utilized in breeding programme to improve level of drought tolerance in Indian mustard cultivars.

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Short communication

Effects of micronutrients on nodulation, nitrogen fixation and yield of soybean, *Glycine max* (L.) in lateritic acid soil of West Bengal

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During the past few decades numerous reports had been made that various trace elements influenced the symbiotic N_2-fixation in legumes. The molybdemum (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 constitute 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 N2-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.

Soybean, *Glycine max* L. cv. Bragg was inoculated with a single strain of *Bradyrhizobium 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. Crop was raised during 4th week of July every year and harvested by end October or 1st week of November. The plot size was 2 m x 2 m. Seed rate was 50 kg/ha, spacing was 30 cm between rows and 10 cm plant to plant. The experiments were designed in Randomized 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) inoculated 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 was recorded from oven dried plants and nitrogen and phosphate contents were estimated as per Jackson (1962). The grain yield was recorded after harvesting the crop. Soil pH : 5.50; 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 methods of Jackson (1962). Available micronutrients were estimated by Atomic Absorption Spectrophotometer (Perkin Elmer, Model 2380) and presented in table 1.

Table 1 Available micronutrients in the soils

	Zn	Fe	B	Mn	Mo	Cu	CD at 5% level
Soybean required	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). 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 47.2 % increment yield. Present findings are in agreement with that of Kabi and Poi (1980) and Posypanoi and Zherkov (1992).

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 wt. (g)/plant		Plant dry wt. (g)/plant		Seed yield (kg/ha)	Yield increase 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	1.2	55.8	0.2	5.5	1091	-	2.5	3.2	0.4	0.3
Zn	12	26	0.245	0.915	1.8	63.1	0.3	7.0	1313	20.3	2.8	3.5	0.4	0.4
Fe	16	26	0.183	0.895	1.7	60.3	0.3	6.1	1093	0.1	2.7	3.3	0.4	0.4
B	16	28	0.285	1.191	2.1	66.0	0.4	7.5	1416	29.7	3.1	3.3	0.4	0.4
Mo	11	27	0.295	1.270	2.3	68.1	0.5	8.0	1596	46.2	3.3	4.0	0.4	0.4
Mixed	14	31	0.367	1.345	2.5	72.1	0.5	8.6	1606	47.1	3.3	4.1	0.4	0.4
CD (P=0.05)	0.75	0.6	NS	0.3	0.2	2.53	NS	0.1	15.5	-	0.0	0.0	0.0	0.0

It was found in the present study that Fe, Mo and B significantly increased the nodule number, nodular fresh weight and N uptake in plant over the inoculated control. It was also found that Mo had maximum influence 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.

Therefore, judicious use of micronutrients was needed for gainful cultivation of soybean in lateritic acid soils.

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Short communication

Effect of irrigation, phosphorus and biofertilizer on growth and yield of summer soybean, *Glycine max* (L.) Merrill under South Gujarat condition

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Soybean, *Glycine max* (L.) Merrill is considered as the wonder legume. It occupies an intermediate position between legumes and oilseeds, containing more protein (40%) than most of the legumes, but less oil (20%) than majority of the oilseed. Soybean is the most nutritive as it contains maximum (64%) lysine. However, its productivity is very low in India due to inadequate water and nutrient management and other management practices. In this context, an experiment was undertaken to find out the effect of irrigation, phosphorus and bio-fertilizer on growth and yield of summer soybean under South Gujarat condition.

A field experiment was conducted during summer, 2001 at College Farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat. The soil of experimental field was clayey in texture having medium to poor drainage, neutral in reaction, low in available nitrogen (237.6 kg/ha), medium in available phosphours (32.35 kg/ha) and high in available potassium (352.0 kg/ha). Field capacity, permanent wilting point and bulk density were 32.9%, 18.2% and 1.42 g/cm^3, respectively in 0-30 cm soil depth. Eighteen treatment combinations consisting of three levels of irrigation *viz.*, 0.4 (I_1), 0.6 (I_2) and 0.8 (I_3) IW/CPE ratios and 60 mm depth of irrigation water. Three levels of phosphorus *viz.*, control (P_0), 30 kg P_2O_5 (P_1) and 60 kg P_2O_5/ha (P_2) and two levels of bio-fertilizer *viz.*, control (B_0) and PSB inoculation (B_1) were tried in a Factorial Randomized Block Design with three replications. The gross and net plot size was 4.5 m x 4.0 m and 3.6 m x 3.0 m, respectively. The experimental plot was fertilized as per treatments with nitrogen and phosphorus in form of urea and single super phosphate, respectively and bunded manually before sowing. Seed of soybean cv. Gujarat Soybean 2 was treated with phosphate solubilizing bacterium culture and thereafter treated and untreated seeds were sown as per treatments in fertilized furrow on 30th January, 2001 using recommended seed rate of 60 kg/ha at 45 cm x 10 cm spacing. Two common irrigations of 60 mm depth were applied for crop establishment. Irrigation water was applied as per treatment to each plot. Irrigation levels *viz.*, I_1, I_2 and I_3 received 5, 7 and 9 irrigations, respectively. The total quantity of irrigation water was applied 300, 420 and 540 mm in respective irrigation treatments.

Effect of irrigation

Growth and yield were significantly influenced by frequent irrigations on the basis of IW/CPE ratio of 0.8 (Table 1). Significantly, the tallest plant (43.3 cm), drymatter accumulation at harvest (41.7 g), maximum number of root nodules at 60 (17.2) and 90 (13.3) days after sowing, a maximum numbers of pods per plant (25.0), seeds/pod (2.6) and 100 seed weight (8.8 g) were recorded with 0.8 IW CPE ratio (I1). This might be due to provision of better nourishment to the crop leading to better growth and yield attributes due to availability of sufficient moisture even at critical growth stages. The results are in confirmation to the findings of Chavan (1997) and Chavan *et al.* (1998).

Irrigating the crop at 0.8 IW/CPE ratio (I_3) produced significantly higher seed (1050 q/ha) and straw (1440 kg/ha) yields over 0.6 (I_2) and 0.4 (I_1) IW/CPE ratios (Table 2). The increase in seed yield was 25 and 50% over I_2 and I_1 treatments, respectively. The remarkable increase in seed and straw yields under treatment I_3 was mainly due to adequate moisture supply throughout the growth period which resulted into better growth and yield attributing characters. These findings are in accordance with those reported by Chavan (1997) and Chavan *et al.* (1998). Among various irrigation treatments, irrigating the soybean at 0.8 IW/CPE ratio with 9 irrigations each of 60 mm depth of irrigation water recorded the highest net return of Rs. 8310/ha with BCR of 2.71 (Table 2).Similar benefits of irrigation were reported by Chavan (1997).

Effect of phosphorus

An appreciable increase in growth parameters *viz.*, plant height, drymatter accumulation per plant and number of root nodules per plant at 60 and 90 days after sowing and yield attributing characters *viz.*, pods/plant, number of seeds/pod and 100 seed weight (Table 1) were noticed with application of 60 kg P_2O_5/ha (P_2) than 30 kg P_2O_5/ha (P_1) and control (P_0). The probable reason for such response might be due to synergistic effects of irrigation and phosphorus and also phosphorus ensures uniform and timely ripening of crop and involved in transformation of energy in higher values of growth and yield attributes. These results are in accordance with those supported by Baskar *et al.* (2000).

Significantly higher yields of seed (10.8 q/ha) and straw (14.6 q/ha) were recorded under higher level of 60 kg P_2O_5/ha (P_2) over 30 kg P_2O_5/ha (P_1) and control (P_0) (Table 2). The increase in seed yield was 31.7 and 54.3% over P_1 and P_0 treatments, respectively. The results are in accordance with those reported by Malik (1996).

The application of 60 kg P_2O_5/ha (P_2) recorded the highest net return of Rs. 8202/ha with benefit cost ratio (BCR) of 2.57. It was due to higher yields of seed and straw registered under this level. Malik (1996) recorded similar economics for soybean crop.

Effect of bio-fertilizer

Growth attributes like plant height, drymatter accumulation, number of root nodules at 60 and 90 days after sowing and yield attributes such as number of pods/plant, number of seeds/pod and 100-seed weight were significantly influenced by phosphate solubilizing bacteria (PSB) inoculation (B_1) over control (B_0). It may be due to favourable effect of phosphate solubilizing bacteria on root growth and thereby increased root activity. Similar results were obtained by Dubey *et al.* (1997) for drymatter accumulation and root nodules while Sharma and Namdeo (1999a) for root nodules and yield attributes.

Biofertilizer (PSB) exerted remarkable effect on seed and straw yields of soybean (Table 2). Significantly the highest seed (100 kg/ha) and straw (1350 kg/ha) yields were recorded with PSB inoculation (B1) over control (B_0). These results corroborate the findings of Sharma and Namdeo (1999a).

The highest net returns of Rs. 6781/ha and BCR value of 2.46 were recorded with PSB inoculation (B_1). Similar benefits of PSB inoculation were reported by Sharma and Namdeo (1999b).

Table 1 Growth and yield attributes of summer soybean as influenced by irrigation, phosphorus and biofertilizer

Treatment	Plant height (cm)	Drymatter accumulation (g)	Root nodules/plant (No.)		Pods/plant (No.)	Seeds/pod (No.)	100 seed weight (g)
			60 DAS	90 DAS			
Irrigation levels (IW/CPE ratio)							
I_1 = 0.4	35.2	38.0	15.5	11.6	21.0	2.3	7.4
I_2 = 0.6	39.4	39.5	17.0	12.3	12.8	2.4	7.9
I_3 = 0.8	43.3	41.7	17.2	13.3	25.0	2.6	8.8
SEm±	1.20	0.49	0.21	0.20	0.57	0.05	0.17
CD (P=0.05)	3.45	1.43	0.61	0.60	1.65	0.14	0.50
Phosphorus levels (kg P_2O_5/ha)							
P_0 = Control	35.1	37.4	15.1	11.2	20.2	2.2	7.2
P_1 = 30	39.4	40.0	17.1	12.6	23.0	2.5	8.0
P_2 = 60	43.4	41.7	17.6	13.4	25.6	2.7	8.9
SEm±	1.20	0.49	0.21	0.20	0.57	0.05	0.17
CD (P=0.05)	3.45	1.43	0.61	0.60	1.65	0.14	0.50
Biofertilizer levels							
B_0 = Control	37.8	39.0	16.3	12.0	22.0	2.3	7.8
B_1 = PSB inoculation	40.8	40.4	16.9	12.8	23.9	2.5	8.2
SEm±	0.98	0.40	0.17	0.17	0.46	0.04	0.14
CD (P=0.05)	2.82	1.17	0.50	0.49	1.35	0.11	0.41

Table 1 **Seed and straw yield (q/ha), protein and oil content (%) and economics of summer soybean as influenced by irrigation, phosphorus and biofertilizer**

Treatment	Yield (q/ha)		Net return (Rs/ha)	BCR
	Seed	Straw		
Irrigation levels (IW/CPE ratio)				
I_1 = 0.4	7.0	11.4	4494.47	2.03
I_2 = 0.6	8.4	12.8	5980.87	2.30
I_3 = 0.8	10.5	14.4	8309.67	2.71
SEm±	0.33	0.50	-	-
CD (P=0.05)	0.96	1.45	-	-
Phosphorus levels (kg P_2O_5/ha)				
P_0 = Control	7.0	11.1	48.04.80	2.20
P_1 = 30	8.2	12.8	5777.60	2.25
P_2 = 60	10.8	14.6	8202.20	2.57
SEm±	0.33	0.50	-	-
CD (P=0.05)	0.96	1.45	-	-
Biofertilizer levels				
B_0 = Control	8.2	12.2	5733.67	2.25
B_1 = PSB inoculation	9.1	13.5	6781.27	2.46
SEm±	0.27	0.41	-	-
CD (P=0.05)	0.79	1.18	-	-

Interaction effect

The irrigation and phosphorus interaction was found to be significant with respect to seed yield. Significantly the highest seed yield recorded under the combination (I_3P_2) of the highest level of irrigation i.e., 0.8 IW/CPE ratio and the highest dose of phosphorus 60 kg P_2O_5/ha (Table 3) as compared to the other combinations. Similar findings were also recorded by Sharma *et al.* (1994) for summer moong.

Table 3 **Seed yield (q/ha) of soybean as influenced by interaction effect of irrigation and phosphorus**

Irrigation	Phosphorus		
	P_0	P_1	P_2
I_1	4.9	6.6	9.5
I_2	7.8	8.0	9.4
I_3	8.2	10.1	13.3
SEm±		0.58	
CD (P=0.05)		1.67	

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Short communication

Screening and identification of resistant sources against soybean, *Glycine max* (L.) Merill defoliators

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Leaf feeding tests under controlled laboratory conditions were used to assess 15 soybean genotypes comprising germplasm sources and some advanced breeding lines developed from them at National Research Centre for Soybean, Indore, MP against tobacco caterpillar *Spodoptera litura* (Fab.). There was a significant variation among the genotypes for leaf consumption in no choice test (NCT), but in general had a higher leaf area eaten than multiple choice test (MCT), implying that under controlled conditions and in no choice conditions *S. litura* larvae are voracious feeders. TGX 855-53D, a germplasm line from Taiwan showed antixenosis (non-preference) reaction to *S. litura* , L 129, a source of resistance to girdle beetle also showed moderate to high resistance against *S. litura* indicating its suitability as a donor for multiple pest resistance. Using the lines as donors would greatly broaden the base of soybean varieties, as these represent a diverse source of germplasm compared to the well used set of Bragg, Lee, Clark 63 and Davis. Advanced generations of the crosses JS 335 x TGX 855-53D and JS 335 x *G. soja* have shown resistance and can be used as pre-breeding material in the breeding programme.

Soybean, *Glycine max* (L.) is the second major oilseed crop of India after groundnut. Its luxurious growth, green foliage of high nutritive value attract many insect pests, which attack soybean during entire growth period. Several studies conducted on soybean at different locations across the country revealed that the yield loss could be over 50% due to insect incidence (Sharma, 1999). Tobacco caterpillar, *Spodoptera litura* (Fab.), is one of the major insect pests of soybean causing severe defoliation and yield losses in India (Singh *et al.*, 1990). Earlier field screening trails revealed that germplasm lines TGX 855-53D and DS 396 were least preferred by defoliators (Sharma, 1991).

The study was carried out under controlled laboratory conditions for two seasons i.e., *kharif*, 2000 and 2001, to screen soybean genotypes, including donors TGX 855-53D, DS 396, L 129, EC 34500 and some advanced breeding lines developed at NRC for Soybean (Sharma, 1995).

Second instar *S. litura* larvae reared from field collected egg masses, were used in the laboratory study. Preference for leaf feeding were assessed by multiple choice test (MCT) and no-choice test (NCT), respectively in 15 soybean genotypes comprising resistant sources, high yielding varieties and breeding lines developed from them, at 26±1°C and 75% relative humidity.

Multiple choice test (MCT): Leaf discs, each of 16 sq. cm were cut from fully expanded top leaves of each genotype and placed in a circular fashion in glass troughs (25 cm diameter) lined with moist filter paper. Thirty second instar larvae (pre-starved for 6 hrs) were released at the centre of each petri dish and they were covered with moist muslin cloth. Three such sets were maintained. After 24 hr, leaf area of individual disc was measured through leaf area meter (CI-202, CID, Inc), used to calculate per cent leaf area consumption.

No choice test (NCT): Pre-measured leaves (16 sq. cm) of 15 genotypes were placed in individual petridishes (4 inch diameter) lined with moist filter paper. Three replicated per genotype were arranged in RBD. One 2nd instar *S. litura* larva (pre-starved for 6 hrs), was released in each petridish. Leaf consumption was recorded after 1, 3 and 5 days after the release of the larvae. Fresh pre-measured leaves were supplied for food on each observation. Mean per cent leaf area consumed per day was noted on the basis of total leaf area provided and the total leaf area left over during the period of study (Cui *et al.*, 1995; Sharma, 1995; Sharma, 1996).

Varietal preference for leaf feeding: Entire cross combinations gave high degree of resistance under MCT compared to their cultivated parents and at par with the donors TGX 855-53D, DS 396, L 129 and EC 34500. NRC 2 was highly susceptible and so was its cross with *Glycine soja*. Basically these crosses were advanced for their higher protein content and no screening was made against defoliator resistance in the early generations. The least preferred line was PK 472 x EC 34500 followed by BC_2F_5 progeny line of JS 335 x *G. soja* and PK 416 x TGX 855-53D. TGX 855-53D, a germplasm line from Taiwan showed a high degree of resistance in MCT with 17% test area eaten while in NCT it gave complete susceptibility with 99% test area eaten indicating an antixenosis (non-preference type) of reaction.

This can be used as a source for developing defoliator tolerant lines. Identification of L 129, a source of resistance to girdle beetle with moderate to high resistance against tobacco caterpillar in both the years of study is of significant importance as this can be used as a source for multiple pest resistance.

No choice test: There is a significant variation among the genotypes for leaf consumption in NCT, but in general had a higher per cent of leaf area eaten than MCT, implying that under controlled conditions and in no choice conditions *S. litura* was voracious feeder and ate any thing - they come across (Table 2). This signified the importance of varietal cafeteria approach to be adopted to minimize the menace of this pest. Further the donor DS 396 had given a stable performance with a good level resistance to *S. litura* larva under both multiple choice test and no choice test conditions of testing indicating its usability as a source of resistance to defoliators. The advanced line JS 335 x TGX 855-53D had also shown little damage to *S. litura* larva under both the conditions of testing indicating its suitability in varietal development and breeding programmes.

Table 1 Per cent leaf area of soybean genotypes consumed by II[nd] instar *S. litura* larvae in MCT

Genotype	2000-01 Leaf area eaten		2001-02 Leaf area eaten		Average Leaf area eaten	
	Sq. cm.	%	Sq. cm.	%	Sq. cm.	%
PK 416 x TGX855-53D	2.0	12	2.7	17	2.3	15
PK 416	10.5	65	9.9	62	10.2	64
TGX855-53D	2.1	13	3.1	20	2.6	16
JS 335 x TGX855-53D	3.1	19	3.0	19	3.0	19
JS 335	8.4	53	9.1	57	8.8	55
JS 335 x *G. soja*	1.6	10	1.7	11	1.7	10
NRC 2 x *G. soja*	12.3	77	12.1	75	12.2	76
NRC 2	13.3	83	13.5	84	13.4	84
NRC 7	6.2	39	6.1	38	6.1	38
L 129	4.4	27	4.7	29	4.5	28
PK 472 x EC 34500	1.3	8	1.5	10	1.4	9
EC 34500	2.5	16	2.7	17	2.6	16
NRC 37	9.8	61	10.6	66	10.2	64
DS 396	4.6	29	4.8	30	4.7	28
PK 472	13.5	85	13.7	86	13.6	85

Table 2 Per cent leaf area of soybean genotypes consumed by II[nd] instar *S. litura* larvae in NCT

Genotype	2000-01 Leaf area eaten		2001-02 Leaf area eaten		Average Leaf area eaten	
	Sq. cm.	%	Sq. cm.	%	Sq. cm.	%
PK 416 x TGX855-53D	7.0	44	7.1	44	7.0	44
PK 416	13.3	83	14.0	87	13.7	85
TGX855-53D	15.8	99	15.8	99	15.9	99
JS 335 x TGX855-53D	2.9	18	3.4	21	3.2	20
JS 335	15.9	99	15.7	98	15.9	99
JS 335 x *G. soja*	5.3	33	5.0	31	5.2	32
NRC 2 x *G. soja*	15.6	98	15.5	97	15.6	97
NRC 2	10.8	67	10.0	62	10.4	65
NRC 7	8.4	52	8.9	55	8.6	54
L 129	4.4	27	5.4	34	4.9	31
PK 472 x EC 34500	16.0	99	15.6	97	15.8	98
EC 34500	5.9	37	6.3	39	6.1	38
NRC 37	12.7	79	13.1	82	12.9	81
DS 396	3.3	20	3.0	19	3.1	20
PK 472	11.3	70	11.2	70	11.2	70

Antixenosis type of resistance as available in TGX855-53D would suffice in regions practicing varietal cafeteria but in regions where monoculture is in vogue use of a true resistant donor line DS 396 as identified by NCT would be more ideal. Further, in areas where both girdle beetle and defoliator damage is significant, use of donors like L129 would be more beneficial. The advanced generations of the crosses so identified, particularly JS 335 x TGX855-53D and JS 335 x *G. soja* should be subjected to agronomic evaluation for their suitability as direct varieties. If not these can be used as pre-breeding material in the breeding programme being undertaken in the AICRPs system. Using TGX855-53D and L129, as donors would greatly broaden the base of soybean varieties as these represent a diverse source of germplasm compared to the well used set of Bragg, Lee, Clark 63 and Davis (Tara Satyavathi, 2002). The repeated use of few parents continuously in the breeding programs has been one of the main cause of the narrow base soybean varieties in India as revealed by the coefficient of parentage studies (Bharadwaj *et al.*, 2001). Further, most of the Indian cultivars were derived from a limited number of common ancestors and the genetic base in terms of average number of parents per variety is reduced because of the repetitive use of the same parents for the development of the genetic stock or breeding material. This led to a sort of inbreeding within a selected group of genotypes that has contributed to the decline in the average number of parents per variety. This trend of narrowing genetic base of the Indian soybean varieties is a major concern and challenge put forward to the Indian soybean breeders (Tara Satyavathi *et al.*, 2003). This challenge may be met through widening the genetic base of the soybean varieties through the efficient use of unexploited variability present in the germplasm as well as developing breeding material that has no common lineage for use in soybean varietal improvement programme.

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Short communication

Wild sesame, *Sesamum indicum* L. species distribution in Kerala

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Three wild species of sesame distributed in Southern Kerala are *Sesamum malabaricum*, *Sesamum mulayanum* and *Sesamum radiatum*. The wild sesame species *viz.*, *Sesamum malabaricum* and *Sesamum mulayanum* have the same chromosome number of cultivated sesame (2n=26) and possess resistance to majority of biotic and abiotic stresses. Hence these species can be utilized for resistance breeding. Since the chromosome number of *Sesamum radiatum* is 2n=64, it is difficult to transfer the genes from this species through conventional breeding methods.

Sesame (*Sesamum indicum* L.) is one of the ancient annual oilseed crops cultivated in Kerala, where the genus exhibited wide diversity. It belongs to family Pedaliaceae. In sesame, a number of wild species found in waste lands and also road side in Kerala which possess potential source of many desirable traits e.g. resistance to pests, diseases and drought.

An extensive survey was conducted for identifying wild sesame from 2002 to 2003 in six southern districts of Kerala *viz.*, Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam and Ernakulam. Observations on habit, habitat and plant population of different species were taken. A detailed study on stem, leaf, glands, root flowers, capsules and seed characters were conducted. Seed quality was assessed through 1000 seed weight and oil content.

In the present investigation three species of wild sesame were identified *viz.*, *Sesamum malabaricum*, *Sesamum mulayanum* and *Sesamum radiatum*. All these species are seen on roadsides and waste lands in Kerala. The wild species *S. malabaricum* and *S. mulayanum* have the same chromosome number (2n=26) to that of cultivated *S. indicum*, while *Sesamum radiatum* chromosome number posses 2n=64. *Sesamum malabaricum*, has been recorded by Desai and Goyal (1981) in Kerala. The same was also recorded in Index Kewensis (Joshi, 1961). The wild species *Sesamum mulayanum* (N.C. Nair, 1963, *Bulletin of Botanical Survey*, **5**:251-252.) and *Sesamum radiatum* (Mathew, 1999) were also reported from Kerala. *Sesamum radiatum* was also reported from Thiruvananthapuram district recently, Kerala (Augustine, 2001)

In the present study the population percentages of *Sesamum malabaricum* is 4.99, *Sesamum mulayanum* is 9.01 and *Sesamum radiatum* is 85.99. Among the three species, *Sesamum radiatum* distributed widely in all districts surveyed (Table 1). Based on the survey conducted in six districts of southern Kerala, the maximum diversity of wild species are seen in Alappuzha district..

Sesamum malabaricum: An erect herb, 146-187 cm height, leaves opposite, trifoliate and toothed below,6.4 to 20.5 cm length and 4.5 cm to 6.5 cm breadth. Upper leaves alternate, narrowly elliptic to lanceolate. Flowers axillary, solitary, shortly pedicelled, purple colour with deep pink spot inside the corolla. Bracts 2 ,green, having two globular yellow glands in the axil of the bracts; calyx green hairy sepals 5,corolla oblique, hairy, glabrous within, lobes 5, 4 equal lips and one longer lip, stamens 4 didynamous, connective surrounded by a yellow gland at the apex, anther cell oblong, suture black in colour, ovary hairy stigma lobed, spatulate, capsule erect, oblong, 2.4x 0.8 cm ,seed obovate, winged, reticulate and black.1000 seed weight 2.3 gm and oil content is 24%. Duration 125-130 days.

Sesamum mulayanum is an erect herb, 60-90 cm height, leaves opposite, trifoliate and toothed below, 9.2 to 15.6 cm length and 3.2 cm to 6 cm breadth. Upper leaves alternate, narrowly elliptic to lanceolate. Flower axillary, solitary, shortly pedicelled, purple colour with deep pink spot inside the corolla Bracts2, green, having two globular yellow glands in the axil of the bracts. Calyx green hairy sepals 5 corolla oblique, hairy, glabrous within, lobes 5, 4 equal lips and one longer lip, stamens 4 didynamous connective surrounded by a yellow gland at the apex, anther cell oblong, suture black in colour, ovary hairy stigma lobed, spatulate, capsule erect, oblong,2.1x.98 cm, seed obovate, winged, reticulate and black in colour.1000 seed weight 2.26 gm. and 32% oil content. 110-120 days duration.

Sesamum radiatum is an erect herb, annual but shows perennial, continuous branching from the base of the stem contributes perennial habit. 145-190 cm height leaves simple, opposite below alternate above the lower leaves ovate and toothed below 12.5 cm to 17.6 cm length and 2.7 cm to 5.6 cm breadth, upper leaves elliptic to lanceolate. Flower axillary, pinkish violet flowers with spotted purple within. Bract 2 having globular deep purple glands in the axil of the bracts, calyx green, lobes 5,hairy. Corolla companulate ,oblique ,pinkish-violet to whitish -rose within and spotted within ,petals 5 four equal and stamen 4, didynamous ,anther oblong, connective surrounded by a purple gland at apex. Ovary dense hairy, stigma 2 lobed, spathulate. Capsule erect, oblong, 4 angled and grooved dense pubescent, splitting apex down ward, seeds many, ovoid, 3x2 mm black, brown with transverse ridges, emanating from a central field on the broad surfaces especially the flatter one. 1000 seed weight 2 gm. and with 33 % seed oil content. six months duration.

Table 1 Distribution of wild sesame species in Kerala

District	Locality	Species
Kottayam	Changanassery	@
	Kuruchy	@#
	Kottayam	@
Ernakulam	Aluva	@
Pathanamthitta	Thiruvalla	@#
	Pandalam	@#
	Adoor	@
Alappuzha	Chenganoor	#*
	Cherthala	@
	Haripad	@#*
	Thottappally	@#*
	Punnappara	@#*
	Ambalapuzha	@#
Kollam	Kollam	@
	Kottarakkara	@
	Nendakara	@#*
	Karunagappally	@#
Thiruvananthapuram	Kilimanoor	@
	Vellayani	@

* *Sesamum malabaricum;* # *Sesamum malabaricum;* @ *Sesamum radiatum*

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Short communication

Effect of gametocides in sesame, *Sesamum indicum* L.

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Sesame (*Sesamum indicum* L.) is one of the important oilseed crops grown in India. The average yield of sesame in India is about 330 kg/ha, which is very low when compared to other countries. Development of hybrids is one of the best methods to increase yield in sesame. By exploiting hybrid vigour, sesame cultivation can be revolutionized. Sesame is predominantly a self-pollinated crop and exploitable heterosis for seed yield to the extent of 328% has been reported by Singh *et al.* (1986) and heterobeltiosis to the extent of 101% has been reported by Naradiya *et al.* (1995). In sesame, hybrid seed is produced by manual emasculation and pollination technique which is time consuming, laborious and costly. Further, there are no reports on the availability of male sterility and its feasible exploitation of heterosis. In recent times it has been observed that male sterility can be induced in plants by application of certain gametocidal compounds (Mohanram and Rustogi, 1966; Dubey and Singh, 1968). These chemicals besides causing male sterility can also exhibit morphological effects such as temporary suspension of stem elongation, death of terminal bud narrowing of leaves and several patterns of leaf chlorosis and in certain cases also affect ovule fertility. Hence, induction of chemical male sterility without affecting ovule fertility and causing phyto-toxicity could have great merit in hybrid seed production in sesame. With these objectives, the present investigation was carried out to study the gametocidal efficacy of some chemicals in inducing male sterility and their effect on other morphological characters.

The experiment was conducted by using cv. Swetha and CO-1 as female and male parents respectively. The treatments comprised of Sodium 2, 3 dichloro-isobutyrate (500, 1000 and 5000 ppm), maleic hydrazide (5000, 10000 and 15000 ppm) and ethereal (500, 1000 and 1500 ppm) sprayed thrice and a control (manual emasculation and pollination with water spray). The first spray of the chemical was done to the female parent at the time of flower bud initiation (i.e., 26-30 days after sowing) and second and third sprays were done at an interval of 10 days from the first spray. The experiment was conducted at College Farm, Acharya N.G. Ranga Agricultural University, Hyderabad during *rabi*, 1999, in Factorial Randomized Block Design with three replications. The chemical maleic hydrazide and ethereal used were of analytical grade obtained from SD Fine Chemicals and Sodium 2,3 dichloroisobutyrate from Fluka, Switzerland Each treatment comprised of four rows of four meters length with an inter-row spacing of 60 cm and intra row spacing of 20 cm. The recommended package of practices were taken to raise a good sesame crop. In each treatment 30 plants from female parent were selected for different studies. Ten plants were used to see the effect of pollen sterility and viability through selfing and laboratory tests, ten plants for ovule fertility by crossing with CO-1 (male parent) and another ten to study morphological traits such as plant height, days to flowering and number of pods/plant. The data was analyzed as per Panse and Sukhatme (1978).

The analysis of variance revealed that there was significant difference between the treatments and number of sprays for all the characters studied. The interaction of treatments and number of sprays was also significant for all the characters except ovule fertility. The data on pollen sterility studies conducted through acetocarmine test and selfing in the field were almost similar. Sodium-2, 3 dichloro-isobutyrate 5000 ppm induced highest pollen sterility (97.8%) and was at par with maleic hydrazide 15000 and 10000 ppm. Further, with increasing concentration there was increase in pollen sterility, while lowest pollen sterility (1.3%) was recorded in control. The present studies are in conformity with the findings of Dubey and Singh (1968). Etheral recorded the lowest pollen sterility among the three chemicals tested. However, etheral had been reported to be a potent gametocide in most of the cereal crops (Mehta *et al.*, 1991). The pollen sterility increased with higher number of sprays. The interaction of treatments and number of sprays was also significant indicting that with increased number of sprays there was higher pollen sterility. Highest pollen sterility was observed with sodium 2,3 dichloro-isobutyrate (5000 ppm) sprayed two and one time and maleic hydrazide (15000 ppm) sprayed one, tow or three times. The results are in agreement with those of Chauhan and Singh (1971) who had reported complete male sterility in sesame with spraying of Sodium 2,3 dichlorosiobutyrate at 0.5 % concentration.

Ovule fertility was maximum in manual emasculation and pollination treatment followed by sodium 2,3-dichloro isobutyrate at 500 ppm. The treatments sodium 2,3 dichloro-isobutyrate 500 ppm had highest ovule fertility followed by 1000 ppm sodium dichloro-isobutyrate and etheral 500 ppm which were at par with each other. Lowest ovule fertility was recorded in etheral at 1500 ppm (45.11%) followed by maleic hydrazide at 1500 ppm (47.3%). In general ovule fertility decreased with increase in the concentration of the chemical. Further, among the chemicals studied sodium 2,3-dichloro isobutyrate had highest ovule fertility followed by etheral and maleic hydrazide. The number of sprays was also significant and the highest ovule fertility was observed when the chemical was sprayed once (65.9%) which was at par with two sprayings (64.5%). In all the treatments with increase in number of sprayings there was decrease in ovule fertility. The interaction of treatments and number of sprays was non-significant.

Table 1 Effect of different chemicals concentrations and number of sprays on pollen sterility and ovule fertility in sesame

Treatment	Pollen sterility (%)				Ovule fertility (%)			
	1 spray	2 sprays	3 sprays	Mean	1 spray	2 sprays	3 sprays	Mean
Sodium 2,3 dichloroisobutyrate 500 ppm	80.0	80.0	80.0	80.0	80.0	78.0	76.0	78.0
Sodium 2,3 dichloroisobutyrate 1000 ppm	88.0	92.0	94.0	91.3	76.0	72.0	68.0	72.0
Sodium 2,3 dichloroisobutyrate 5000 ppm	95.3	98.0	100.0	97.8	60.0	57.7	56.0	57.9
Maleic hydrazide 5000 ppm	80.0	82.0	86.0	82.7	62.7	62.7	60.0	61.8
Maleic hydrazide 10000 ppm	92.0	94.0	96.0	94.2	52.0	52.0	50.0	51.3
Maleic hydrazide 15000 ppm	96.0	97.0	98.0	97.0	48.0	48.0	46.0	47.3
Etheral 500 ppm	38.0	58.7	67.3	54.7	72.0	70.0	67.0	69.7
Etheral 1000 ppm	46.7	68.0	77.3	64.0	59.0	64.7	54.0	59.2
Etheral 1500 ppm	47.7	72.0	76.0	65.2	50.7	41.7	43.0	45.1
Manual emasculation/water spray	1.3	1.3	1.3	1.3	99.0	98	98.0	98.4
Mean	66.5	74.3	78.5		65.9	64.5	61.8	
	SEm±		CD (P=0.05)		SEm±		CD (P=0.05)	
Treatments	1.20		3.33		1.25		3.45	
Sprays	0.66		1.82		0.68		1.89	
Interactions	2.08		5.77		2.16		NS	

There was significant delay in flowering with all the three chemicals sprayed. Maximum delay in flowering was observed with etheral followed by maleic hydrazide and least in sodium 2,3 dichloroisobutyrate. At higher concentration and with higher sprays the delay in flowering was more pronounced. Maximum delay in flowering (33 days) was observed with etheral at 1500 ppm sprayed thrice when compared to control. There was marked reduction in plant height and number of pods per plant with maleic hydrazide at all concentrations and with etheral at higher concentrations. The average plant height, and number of pods/plant were higher in untreated plants than that of treated plants. The effect was more pronounced at higher concentration and with increased sprays. These findings are in agreement with that of Dubey and Singh (1968) and Chauhan and Singh (1971). From the present study it can be concluded that sodium 2,3 dichloroisobutyrate at 5000 ppm sprayed thrice starting from initiation of flowering can induce male sterility up to 99% with high ovule fertility. The chemical had least phytotoxicity effect when compared to other chemicals. However, further studies are to be conducted to increase the outcrossing rate in sesame before it is commercially exploited.

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Short communication

Effect of irrigation and sulphur on yield attributes and yield, oil content and oil yield and consumptive use efficiency of summer sesame, *Sesamum indicum* L.

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Among the major oilseeds crop cultivated in India, sesame ranks third in area and production and India is the world's largest producers of sesame. It is an important source of oil and protein. Presently our cultivated land is limited and maximum utilization is reached, so main emphasis should be given on vertical increase of oil seeds production instead of horizontal expansion. Very little attention has so far been given to work out the nutritional requirement of this crop under different climatic conditions of India. Most of the research works have been carried out mainly to study the effect of N, P and K on sesame crop. But it has been found that different secondary and micro-nutrients like sulphur, zinc, calcium, boron, molybdenum etc. have a very significant effect on growth, seed yield and oil content of oilseeds (Das and Das, 1995). Irrigation also plays an important role on seed and oil yield of sesame. Narang and Gill (1998) reported that seed yield of summer sesame increased with increase in the number of irrigation from 0 to 3. Under lateritic belt of West Bengal, very little work has been done on effect of sulphur under different irrigation levels for improving seed yield and oil yield. Hence, the present investigation was undertaken to study the effect of sulphur on yield and yield components, oil content and water use of sesame under different levels of irrigations.

The field experiment was carried out during the summer season of 1997 and 1999 at the Farm of Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal. The soil was sandy loam (56.4% sand, 24.8 silt and 18.8 clay), acidic in reaction (pH 5.4) having 0.036% total N, 38.2 kg/ha available P, 137.6 kg/ha available K and 26.61 kg/ha available S. *The farm was located at about* 23°39' N and 87°42' E longitude with an average altitude of 58.9 m above the mean sea level under subhumid and semi arid tropic having a little extreme of weather condition. The treatments comprised with four levels of irrigations and four levels of sulphur application. The experiment was laid out in Split Plot Design (irrigation levels were in main plots and sulphur levels were in sub-plots) replicated thrice. Sesame variety Rama was shown on 21st March in 1997 and 8th March in 1999 at a spacing of 30 cm x 10 cm with seed rate of 4 kg/ha. A basal dose of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha was applied in the form of urea, DAP and muriate of potash. Sulphur was also applied as basal dose in the form of elemental sulphur. The data on yield attributes and yields were recorded at maturity after harvesting and threshing the crop whereas oil content in seeds were estimated by using Soxhlet's extraction method. Water used consumptively by the crop was calculated by soil moisture depletion method. Rainfall received during the cropping season were 223.8 and 204.2 mm in 1997 and 1999 respectively.

Yield attributes: The highest number of branches/m^2, capsule/plant, seeds/capsule and test weight (1000 seed weight) were recorded under four levels of irrigation applied at 4-6 leaf stage, branching, flowering and capsule development stages whereas only one irrigation applied at flowering stage produced minimum yield contributing components. The crop experienced moisture stress condition during other critical growth stages when irrigation water applied once at flowering stage. Hence, the crop did not perform better under one and two irrigations. Similar results were also reported by Majumdar and Pal (1988).

Yield components of sesame also significantly influenced by sulphur fertilization except test weight (Table 1). Minimum number of branches, capsule, seed number and 1000-seed weight were observed in crops without any sulphur application and were increased steadily with the increase in sulphur level upto 45 kg/ha. Sulphur level 45 kg/h produced the maximum yield contributing characters though the effect was at par with sulphur level of 30 kg/ha. Sulphur fertilization might have benefitted the growth and development of the crop caused improved yield components under 30 kg and 45 kg S/ha.

Seed yield, stick yield and harvest index: Seed yield, stick yield and harvest index significant influenced by irrigation water. Maximum seed yield, stick yield and harvest index were recorded with the application of highest level of irrigation (4 irrigations) and this was significantly superior to the lower levels except stick yield. Seed yield increased by 14.51, 32.43 and 63.14% whereas stick yield was increased by 3.81, 10.76 and 24.62% with four irrigations over three, two and one irrigations respectively. Four irrigations at all the critical growth stages improved all the yield components of sesame which contributed to significantly greater seed and stick yield of sesame. The results are in agreement with the findings reported by Ayyaswamy and Kudandaivelu (1993).

Table 1 . Effect of sulphur and irrigation on yield attributes and yields of sesame (Mean data of two years)

Treatment	No. of branches/m^2	No. of capsule / plant	No. of seeds/ capsule	Test weight (g)	Seed yield (kg/ha)	Stick yield (kg/ha)	HI (%)	Oil content in seed (%)	Oil yield (kg/ha)
Levels of Irrigation									
F	145	39	42	2.8	593	1553	26.7	43.5	258.6
B+F	158	40	43	2.9	731	1748	28.6	45.4	332.1
B+F+Cd.	171	41	44	3.0	845	1864	30.2	47.0	398.5
L+B+F+Cd.	181	42	45	3.2	968	1936	32.3	49.0	475.1
S Em ±	5.6	0..5	0.6	0.05	16.8	27.6	0.57	0.66	12.78
CD (P = 0.05)	19.2	1.6	2.0	0.18	58.2	95.5	1.97	2.29	44.23
Level of sulphur (kg/ha)									
0	155	40	42	2.9	749	1673	29.8	43.5	327.9
15	162	40	43	3.0	775	1759	29.4	46.0	359.8
30	167	41	44	3.0	798	1809	29.4	47.3	380.9
45	171	42	44	3.0	815	1859	29.2	48.1	395.7
S Em ±	3.2	0.4	0.4	0.03	12.1	36.4	0.24	0.32	5.91
CD (P = 0.05)	9.6	1.3	1.1	NS	35.2	106.3	NS	0.94	17.30

L = 4-6 Leaf stage, B = Branching stage, F = Flowering stage, Cd = Capsule development stage

Sulphur application improved most of the yield attributing components and hence seed and stick yield of this crop increased significantly. The highest seed and stick yield were obtained from the crop receiving 45 kg S/ha though it was at par with that of 30 kg S/ha. These findings are in close conformity with the findings made by Nageshwar *et al.* (1995). Sulphur level did not influence harvest index significantly though maximum harvest index was observed under control (S_0) condition. The result indicated that sulphur although beneficially improved the grain yield of this crop but it increased stick yield to a greater extent and thus, decreased the harvest index.

Oil content and oil yield: Maximum oil content and oil yield were recorded with application of highest level of irrigation (4 irrigations). As water is only media to transport assimilates and minerals, irrigation water application helped in proper seed development resulted increased oil content in sesame and improvement of seed yield as well as oil content of seed caused highest oil yield of summer sesame at four levels of irrigation.

The highest percentage of oil (48.10%) and oil yield (395.67 kg/ha) of sesame were recorded with application of the highest level of sulphur (45 kg/ha) though the effect was not significant with that of 30 kg S/ha and lowest oil content and oil yield were found at control plots Saha and Mandal (2000) obtained similar result.

Consumptive use (20.33 cm) and consumptive use efficiency (29.39 kg/ha-cm) of sesame were lowest under one irrigation treatment and increased with increase in levels of irrigation water. 45 kg S/ha recorded the highest consumptive use (25.57cm) but crops received zero levels of sulphur recorded higher consumptive use efficiency (34.53 kg/ha-cm) than other levels of sulphur application.

It is therefore concluded that the need for the application of four irrigations and 30-45kg S/ha for obtaining high yield of summer sesame under this sub-humid, sub-tropical red and lateritic belt of West Bengal.

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Short communication

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

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In sunflower, a cross-pollinated crop, combining ability is of special significance to identify potential lines to be used to develop heterotic/promising hybrids. To initiate the hybrid-breeding programme, the evaluation of inbred lines for their combining ability is important. The information on the relative magnitude of components of genetic variance from combining ability studies can be exploited for the improvement of traits by utilizing suitable breeding methodology. Hence the present study was undertaken to estimate the general combining ability of lines as well as testers and specific combining ability of crosses for some of the important traits in sunflower.

Four CMS lines were crossed to 8 elite inbred lines to develop 32 F_1 hybrids during kharif, 2001 (Table 2). The 32 F_1 hybrids, their 12 parents and 4 standard checks *viz.*, KBSH- 1, PAC- 1091, MSFH- 17 and APSH - 11 were evaluated during *rabi*, 2001 - 02 in a randomized block design replicated twice. The entries were sown in single rows of length 3 m with uniform spacing of 60 X 30 cm between rows and plants. Recommended package of practices were adapted to raise healthy crop. Data were recorded on five randomly selected plants per entry in each replication for the important traits *viz.*, days to first flowering, days to 50 % flowering, plant height, stem diameter, head diameter, number of filled seeds/head, number of unfilled seeds/head, seed filling (%), 100 seed weight, seed yield and oil content. Combining ability analysis was carried out as suggested by Kempthorne (1957).

Analysis of variance for combining ability revealed that all the genotypes exhibited significant differences among themselves for all the traits studied. The parents as well as crosses exhibited significant differences for all the traits whereas parents vs. crosses exhibited significant differences for nine traits excluding days to first flowering, days to 50 % flowering and number of unfilled seeds/ head. The effects of both lines and testers were found to be significant on all the characters except days to maturity for which only lines were significant. The interaction effects (lines x testers) were found to be significant for all the traits.

Estimates of General Combining Ability (*gca*): Estimates of *gca* effects of different characters in sunflower (Table 1) indicated that among lines RHA 271 and RHA 344 were the best combiners for traits days to first flowering as well as 50 % flowering because they recorded desirable significant negative *gca* effects for both the traits. RHA 345 and DRS 1 were best combiners for plant height since they recorded significant negative *gca* effects. For the trait stem diameter lines RHA 265 and RHA 345 were good general combiners whereas RHA 298 and RHA 346 were best combiners for head diameter. RHA 265 and RHA 341 registered positive *gca* effects for number of filled seeds/head. Lines RHA 346 and RHA 344 were best combiners for the traits 100 seed weight and seed yield/plant, while for oil content, DRS 1 and RHA 344 were best combiners.

Among testers, DCMS 22B was found to be a very good combiner for the yield and yield components as it registered high *gca* effects for stem diameter, head diameter, number of filled seeds/head, seed filling (%), 100 seed weight, seed yield/plant and oil content. CMS 378B was found to be a good combiner for days to first flowering, days to 50 % flowering and plant height since it recorded significant negative *gca* effects. (Table 1).

Estimates of specific combining ability: Nine out of 32 crosses exhibited significant negative *sca* effects for days to first flowering (Table 2). The crosses DCMS 22A x RHA 341, CMS 378A x RHA 345, CMS 7-1A x DRS1, CMS 378A x RHA 344 and CMS 7-1A x RHA 346 exhibited high negative *sca* effects for days to first flowering. For days to 50 % flowering eight hybrids showed significant negative *sca* effects and the earlier were CMS 378A x RHA 345(-5.61), DCMS 22A x RHA 341(-3.17), CMS 343A x RHA 344(-2.23), DCMS 22Ax DRS 1 (-2.17) and CMS 7-1A x RHA 346(-1.98). In six cross combinations significant negative *sca* effects (desirable direction) were observed for days to maturity. Cross combinations CMS 343A x RHA 344 (-3.52), DCMS 22A x RHA 341(-2.20), CMS 7-1A x DRS 1(-2.08), CMS 378A x RHA 345 (-1.83) and CMS 343A x RHA 271 (-1.77) exhibited high negative *sca* effects. The results are in accordance with Giriraj *et al.*, (1987), Kumar *et al.*, (1998) and Limbore *et al.*,(1997). Significant effects for dwarfness were exhibited by four cross combinations *viz.*, DCMS 22A x DRS 1(-12.78), CMS 7-1A x RHA 271 (-9.84), CMS 378A x RHA 341 (-8.51) and

CMS 378A x RHA 265 (-7.18). Setty and Singh (1977), Kadkol *et al.*, (1984) and Limbore *et al.*, (1997) also reported highly significant *sca* effects for dwarfness.

Ten cross combinations exhibited significant effects for stem diameter. The crosses with highly positive *sca* effects were CMS 7-1A x RHA 341 (0.74), CMS 343A x RHA 345 (0.55), CMS 343A x RHA 265 (0.48), CMS 378A x RHA 344 (0.48) and CMS 378A x RHA 346 (0.36). For head diameter 10 hybrids exhibited significant positive *sca* effects among them CMS 343A x RHA 346 (5.60), CMS 378A x RHA 344 (5.21), CMS 7-1A x RHA 341 (5.19), DCMS 22A x RHA 298 (3.86) and CMS 343A x RHA 345 (2.90) showed high *sca* effects. Lande *et al.* (1997) and Nirmala *et al.* (1999) observed high positive *sca* effects for head diameter.

For the trait number of filled seeds/head significant positive *sca* effects were observed in 15 crosses. The cross combinations, CMS 343A x RHA 298 (307.69), CMS 378A x RHA 344 (171.25), CMS 378A x DRS 1 (166), DCMS 22A x RHA 345 (146.75), and CMS 378A x RHA 346 (145.62) exhibited high *sca* effects. Ten crosses showed significant negative *sca* effects for number of unfilled seeds/head. Highly significant negative *sca* effects were observed in the crosses.

CMS 343A x RHA 345 (-33.55), DCMS 22A x RHA 341 (-26.19), CMS 7-1A x RHA 344 (-22.29), DCMS 22A x RHA 298 (-17.02) and DCMS 22A x RHA 265 (-10.98). Thirteen crosses registered significant positive *sca* effects for the trait seed filling per cent. CMS 343A x RHA 298 (4.58), CMS 378A x DRS 1 (4.42), CMS 7-1A x RHA 345 (3.81), CMS 378A x RHA 346 (2.98) and DCMS 22A x RHA 298 (2.91) cross combinations exhibited significant positive *sca* effects (Table 2).

For 100 seed weight, 11 F_1 hybrids exhibited positive significant *sca* effects. Among them, CMS 7-1A x RHA 341 (2.03), DCMS 22A x RHA 298 (1.81), CMS 343A x RHA 271 (1.35), DCMS 22A x DRS 1 (1.04) and CMS 378A x RHA 344 (1.03) recorded significant *sca* effects. Out of 32 hybrids studied, 16 exhibited positive *sca* effects for oil content. The superior cross combinations were CMS 7-1A x RHA 346 (6.42), DCMS 22A x RHA 271 (5.35), CMS 378A x RHA 265 (5.15), CMS 7-1A x RHA 344 (3.67) and CMS 378A x RHA 345 (2.50) (Table 2). Setty and Singh (1977), Kadkol *et al.* (1984), Gangappa *et al.* (1997) and Kumar *et al.* (1998) observed high positive *sca* effects for hundred seed weight and oil content.

Fifteen hybrids recorded significant positive *sca* effects for the trait seed yield/plant. Out of these 15 cross combinations, six crosses involved parents with either high x low or low x high *gca* effects, while two crosses involved both parents with low *gca* effects. The remaining seven crosses involved parents with high x high *gca* effects (Table 3). The ideal cross combination to be exploited is one where high magnitude of *sca* is present in addition to high *gca* in both or at least one of the parents. For this trait Setty and Singh (1977), Kadkol *et al.* (1984), Giriraj *et al.* (1987), Govindaraju *et al.* (1992) and Nirmala *et al.* (1999) recorded high positive *sca* effects.

Table 1 Estimates of general combining ability (*gca*) effects for lines and testers for 12 traits in sunflower

Source	Days to first flowering	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	Seed filling (%)	100 seed weight (g)	Seed yield/plant (g)	Oil content (%)
Testers												
DCMS 22B	-0.52**	0.05	0.33	4.03**	0.18**	2.36**	114.50**	-2.17	2.82**	0.81**	9.92**	1.66**
CMS 343 B	0.17	0.11	-0.11	4.57**	0.04	1.80**	60.69**	-5.63**	2.08**	-0.08**	0.55**	-1.32**
CMS 378 B	-3.02**	-2.39**	0.33	-5.79**	-0.06*	0.41**	22.00**	19.69**	-1.62**	0.63**	4.53**	1.18**
CMS 7-1 B	3.36**	2.23**	-0.55**	-2.81*	-0.15**	-4.58**	-197.19**	-11.89**	-3.28**	-1.36**	-15.00**	-1.52**
SE_i	0.15	0.18	0.23	1.17	0.03	0.14	1.77	1.13	0.12	0.03	0.19	0.07
Lines												
RHA 265	2.98**	2.42**	0.70	3.53*	0.15	0.03	59.56**	11.62**	-0.55**	-0.15**	1.78**	-2.56**
RHA 271	-3.52**	-1.20**	-0.55	-3.09	-0.08*	-0.94**	-77.94**	-21.37**	1.42**	-0.39**	-5.83	0.08
RHA 298	0.86**	0.17	-0.70*	2.93	-0.02	1.53**	-1.06	4.27	-1.84**	0.16**	0.10	-0.02
RHA 341	-1.52**	-1.08**	-0.55	-2.04	-0.08*	-0.35	46.31**	-1.35	1.48**	0.23**	1.97**	0.11
RHA 344	-2.52**	-1.58**	-1.80**	6.13**	-0.10**	-0.47*	-21.94**	5.61**	-0.75**	0.44**	2.80**	1.04**
RHA 345	2.98**	3.30**	1.58**	-7.89**	0.21**	0.26	-37.94**	-8.21**	0.79**	-0.73**	-5.81**	-1.24**
RHA 346	0.11	-0.45	0.70*	4.33*	-0.06	0.76**	-5.31*	10.66**	0.89**	0.48**	3.37**	-1.09**
DRS 1	0.61**	-1.58**	-0.80*	-3.89*	-0.03	-0.82**	38.31**	20.08**	-1.44**	-0.04	1.63**	3.57**
SE_j	0.23	0.28	0.36	1.79	0.04	0.22	2.70	1.73	0.19	0.04	0.29	0.11

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

Table 2 Estimates of specific combining ability (*sca*) for 12 characters in sunflower

Cross	Days to first flowering	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	Seed filling (%)	100 seed weight (g)	Seed yield/plant (g)	Oil content (%)
DCMS 22A X RHA 265	-0.86	-0.17	0.05	8.39**	0.13*	-0.14	53.25**	-10.98**	1.99**	-0.74**	-3.32**	1.61**
DCMS 22A X RHA 271	0.64	0.45	-0.20	8.62**	-0.08	-2.56**	-17.25**	21.41**	-3.02**	-0.94**	-7.5**	5.35**
DCMS 22A X RHA 298	0.27	1.58**	0.55	-0.31	-0.08	3.86**	-20.62**	-17.02**	2.91**	1.81**	13.01**	-0.27
DCMS 22A X RHA 341	-2.86**	-3.17**	-2.20**	-1.23	-0.42**	-1.85**	-85.50**	-26.19**	1.02**	-0.29**	-4.3**	1.21**
DCMS 22A X RHA 344	2.14**	0.33	1.55*	-4.51	0.02	0.76*	-70.25**	-1.91	-1.21**	-0.31**	-6.69**	-3.37**
DCMS 22A X RHA 345	1.64**	2.45**	1.67**	1.52	0.25**	0.84*	146.75**	37.70**	-2.02**	0.08	6.07**	-0.97**
DCMS 22A X RHA 346	0.52	0.70	-0.45	0.29	-0.05	-2.58**	20.12**	5.66	-0.14	-0.66**	-3.85**	0.15
DCMS 22A X DRS 1	-1.48**	-2.17**	-0.95	-12.78**	0.23	1.66**	-26.50**	-8.68**	0.47	1.04**	6.59**	-3.71**
CMS 343A X RHA 265	-0.55	-0.23	-0.02	0.86	0.48**	0.82*	81.06**	-1.60	1.85**	0.23**	5.50**	-0.94**
CMS 343A X RHA 271	-0.55	-1.61**	-1.77**	1.68	-0.20**	0.20	44.56**	-7.72**	1.76**	1.35**	11.16**	-1.54**
CMS 343A X RHA 298	-0.42	-0.98**	1.98*	-4.14	0.07	-0.48	307.69**	10.33**	4.58**	-1.38**	1.52**	0.74**
CMS 343A X RHA 341	2.45**	1.27**	2.23**	0.33	0.15*	-3.09**	94.81**	24.60**	-1.39**	-1.27**	-3.79**	1.36**
CMS 343A X RHA 344	-1.05**	-2.23**	-3.52**	0.96	-0.55**	-4.08**	-47.44**	-1.83	-0.70*	-0.06	-2.88**	2.28**
CMS 343A X RHA 345	-0.55	1.89**	0.61	2.88	0.55**	2.90*	-280.44**	-33.55**	-1.74**	0.19**	-9.22**	0.66**
CMS 343A X RHA 346	0.33	0.64	-0.02	0.06	-0.40	5.60**	-52.56**	-2.71	-0.05	1.02**	4.11**	-3.19**
CMS 343A X DRS 1	0.33	1.27**	0.48	-2.62	-0.11	-1.88**	-147.69**	12.50**	-4.31**	-0.07	-6.40**	0.62**
CMS 378A X RHA 265	0.64	-0.73	-0.45	-7.18*	-0.33*	-0.19	-68.25**	-7.71**	0.39	0.87**	1.92**	5.15**
CMS 378A X RHA 271	-0.86*	1.89**	-0.20	-0.46	0.21**	0.39	-83.75**	-9.02**	-1.20**	-0.97**	-9.22**	-1.59**
CMS 378A X RHA 298	-0.23	-0.48	-0.95	9.42**	0.06	-1.69**	-226.62**	1.57	-5.48**	-0.07	-11.56**	-2.60**
CMS 378A X RHA 341	0.14	0.77	-0.70	-8.51**	-0.46**	-0.25	-115.50**	-3.32	-2.10**	-0.47**	-7.27**	1.75**
CMS 378A X RHA 344	-2.36**	1.27**	1.55*	3.92	0.48**	5.21**	171.25**	26.03**	1.03**	1.30**	15.74**	-2.58**
CMS 378A X RHA 345	-2.86**	-5.61**	-1.83**	-1.16	-0.39**	-2.71**	11.25*	0.54	-0.05	0.35**	2.00**	2.50**
CMS 378A X RHA 346	1.52**	0.64	0.05	0.82	0.36**	-1.11**	145.62**	1.76	2.98**	-0.05	6.48**	-3.38**
CMS 378A X DRS 1	4.02**	2.27**	2.55**	3.14	0.06	0.36	166.00**	-9.86**	4.42**	-0.69**	1.91**	0.75**
CMS 7-1A X RHA 265	0.77	1.14*	0.42	-2.07	-0.29**	-0.50	-66.06**	20.29**	-4.23**	-0.36**	-4.10**	-5.83**
CMS 7-1A X RHA 271	0.77	-0.73	2.17**	-9.84**	0.06	1.98**	56.44**	-4.68	2.46**	0.56**	5.57**	-2.22**
CMS 7-1A X RHA 298	0.39	-0.11	-1.58**	-4.97	0.06	-1.70**	-60.44**	5.12	-2.02**	-0.36**	-2.97**	2.13**
CMS 7-1A X RHA 341	0.27	1.14**	0.67	9.41**	0.74**	5.19**	106.19**	4.91	2.48**	2.03**	15.37**	-4.33**
CMS 7-1A X RHA 344	1.27**	0.64	0.42	-0.37	0.05	-1.90**	-53.56**	-22.29**	0.88**	-0.66**	-6.17**	3.67**
CMS 7-1A X RHA 345	1.77**	1.27**	-0.45	-3.24	-0.41**	-1.02**	122.44**	-4.69	3.81**	-0.62**	1.14*	-2.19**
CMS 7-1A X RHA 346	-2.36**	-1.98**	0.42	-1.17	0.09	-1.92**	-113.19**	-4.71	-2.80**	-0.31**	-6.73**	6.42**
CMS 7-1A X DRS 1	-2.86**	-1.36**	-2.08**	12.26**	-0.18**	-0.15	8.19*	6.04*	-0.58	0.28**	-2.10**	2.35**
SE_{ij}	0.40	0.48	0.62	3.10	0.07	0.38	4.67	2.99	0.32	0.07	0.50	0.19

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

Table 3 Combining ability in relation to heterosis for seed yield/plant in promising hybrids of sunflower

Cross	Seed yield/plant (g)	Heterosis (%) over		*sca* effect	*gca* effect		
		MP	BP		Line	Tester	
CMS 378A X RHA 344	51.10	418.78**	307.17**	15.74**	2.80**	4.53**	h x h
CMS 7-1A X RHA 341	30.35	212.08**	153.97**	15.37**	1.97**	-15.00**	h x l
DCMS 22A X RHA 298	51.05	394.43**	355.80**	13.01**	0.10	9.92**	l x h
CMS 343A X RHA 271	33.90	208.95**	169.64**	11.16**	-5.83**	0.55**	l x h
DCMS 22A X DRS 1	46.15	175.55**	91.91**	6.59**	1.63**	9.92**	h x h
CMS 378 A X RHA 346	42.40	486.85**	480.82**	6.48**	3.37**	4.53**	h x h
DCMS 22A X RHA 345	38.20	443.77**	304.23**	6.07**	-5.81**	9.92**	l x h
CMS 7-1A X RHA 271	12.75	-4.85**	-33.94**	5.57**	-5.83**	-15.00**	l x l
CMS 343A X RHA 265	35.85	105.74**	35.28**	5.50**	1.78**	0.55**	h x h
CMS 343 A X RHA 346	36.05	360.70**	331.74**	4.11**	3.37**	0.55**	h x h
CMS 378 A X RHA 345	28.75	389.36**	302.10**	2.00**	-5.81**	4.53**	l x h
CMS 378 A X RHA 341	36.25	115.45**	36.79**	1.92**	1.97**	4.53**	h x h
CMS 378 A X DRS 1	36.10	131.41**	50.10**	1.91**	1.63**	4.53**	h x h
CMS 343A X RHA 298	30.20	208.95**	169.64**	1.52**	0.10	0.55**	l x h
CMS 7-1A X RHA 345	8.35	38.02**	11.33**	1.14**	-5.81**	-15.00**	l x l

MP = Mid parent; BP = Better parent; h= high; l= low; *: Significant at 5 per cent level; **: Significant at 1 per cent level

The magnitude of *sca* variance indicated that all the characters are governed by non- additive gene action. Since there is preponderance of non-additive gene action over additive in most of the traits, to coin both additive and non-additive gene action and to release the variability and improve the character the breeder should follow Reciprocal Recurrent Selection method to improve the base population and to broaden the genetic base.

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Short communication

Character association studies in advanced sunflower, *Helianthus annuus* L. lines derived from interspecific crosses

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In spite of the high genetic potential available in varieties and hybrids, the productivity of sunflower in India still hovers around 500-600 kg/ha. This is often attributed to narrow genetic base rendering the crop susceptible to various pests and diseases. There is a large scope to diversify the genetic base of the crop using the rich variation available in wild relatives of sunflower (Seiler, 1992). While doing so, unwarranted gene combinations that appear in the interspecific hybridization programs might limit the utility of interspecific derived lines. Hence, the lines derived from interspecific crosses need to be assessed for their breeding value prior to their utilization in crop improvement programs. Therefore, some of the stabilized sunflower lines derived from five interspecific crosses were studied for a number of agronomic parameters and reaction to important diseases. The association between plant traits, their direct and indirect effects on seed and oil yield in the interspecific derived material are reported here.

The material for the experiment comprised of 144 accessions that included 137 advanced lines derived from interspecific crosses involving 4 wild species including seven known accessions of cultivated sunflower (*H. annuus*) as shown below:

Pedigree	Generation	# of cultures
A) Interspecific derived lines		
H. argophyllus x *H. annuus*	BC_4F_4	36
H. petiolaris x *H. annuus*	BC_4F_4	34
H. annuus(wild) x *H. annuus*	BC_3F_5	18
(*H. argophyllus* x *H. annuus* (wild)) x ***H. annuus***	BC_3F_4	30
H. annuus x *H. debilis*	BC_4F_4	19
B) Checks		
Morden	Popular variety	1
PAC1091, KBSH-1	Popular hybrids	2
6D-1, R-265, HA 234, HA 336	Promising parental lines of released hybrids	4

The study was conducted at the experiment station, GKVK campus, University of Agricultural Sciences, Bangalore during *kharif*, 2001. The lines were sown with the spacing of 60 cm between rows and 30 cm with in a row in 12 x 12 Simple Lattice design in two replications. Each replication consisted of 12 blocks and with in each block 12 lines were sown. The replications, blocks and the lines within a block were randomized. Each line having 12 plants was grown in a row of 3.6 meters. Two seeds were dibbled in each hill to facilitate better emergence and to provide uniform plant stand. Thinning was attended on 15^{th} day after sowing to retain one plant/hill. All the recommended agronomic practices were followed to facilitate good growth and to raise a successful crop. From each line in each replication 5 competitive plants were tagged at random. Except days to 50% flowering, all other observations on quantitative characters were recorded at maturity. Correlation coefficient of various pairs of characters was calculated in addition to path analysis to find out the relative contribution of different independent metric traits towards dependent seed yield and oil yield.

Correlation coefficients: Upon close observation of values of correlation coefficients both at genotypic and phenotypic levels, it was evident that plant height, stem girth, head diameter, days to maturity, number of leaves/plant, volume weight and test weight have positive significant correlation with all the three important traits *viz.*, seed yield/plant, oil yield/plant and oil content (Table 1). Imposing selection on the above characters would lead to simultaneous improvement in economic traits. It was also evident that oil yield/plant and seed yield/plant; seed yield/plant and oil content; oil yield/plant and oil content were positively and significantly correlated. Oil yield/plant was also negatively associated with hull content and *Alternaria* severity. So selection for reduced disease severity, lower hull content, higher test weight etc. will improve seed yield, oil content and oil yield/plant.

In some of the earlier works (Srinivasa, 1982; Chikkadevaiah *et. al.*, 1995; Patil *et. al.*, 1996;), it is reported that seed yield/plant and oil content are negatively associated in sunflower. Nevertheless, in the material involved in this study, which are the derivative of interspecific crossing, this undesirable association was not forthcoming, as seed yield and oil content were found positively associated. The utilization of this material in the current breeding efforts as parents might help in improving the oil content and seed yield of resultant lines.

Path analysis for seed and oil yield: At genotypic level, highest positive direct effects on seed yield were observed through test weight (1.179) followed by stem girth (0.551). For oil yield, highest positive direct effect was from seed yield/plant (0.961) followed by oil content (0.579). *Alternaria* severity has considerable negative direct effects on seed yield (Table 2). It is conspicuous from the above that selection for less *Alternaria* severity and more of stem girth will improve the seed yield/plant and ultimately oil yield/plant.

Table 1 Genotypic correlations for 17 characters in 144 lines of sunflower

Characters	D50F	PDI	XLP	NUP	DMT	HDM	SGT	PHT	VWT	SLN	SWD	TWT	HCT	SYP	OYP	OCT
PAU	0.354**	0.066	-0.049	0.229**	0.20**	-0.287**	-0.042	0.14	0.048	-0.114	-0.39**	-0.296**	0.083	-0.139	-0.09	0.120
D50F		-0.177*	0.363**	0.568**	0.859**	-0.074	0.438**	0.629**	0.412**	-0.245**	-0.342**	-0.243**	-0.007	0.137	0.22**	0.42**
PDI			-0.754**	-0.497**	-0.457**	-0.576**	-0.743**	-0.634**	-0.596**	-0.353**	-0.229**	-0.698**	0.343**	-0.971**	-0.767**	-0.62**
XLP				0.759**	0.593**	0.646**	0.745**	0.684**	0.655**	0.16	0.254**	0.695**	-0.30**	0.765**	0.755**	0.67**
NUP					0.661**	0.353**	0.567**	0.598**	0.42**	0.182*	0.132	0.39**	0.175*	0.548**	0.600**	0.48**
DMT						0.21**	0.737**	0.816**	0.661**	-0.092	-0.064	0.136	-0.297**	0.452**	0.489**	0.71**
HDM							0.661**	0.455**	0.395**	0.339**	0.539**	0.722**	-0.311**	0.785**	0.696**	0.35**
SGT								0.885**	0.821**	0.178*	0.202*	0.561**	-0.529**	0.838**	0.815**	0.79**
PHT									0.819**	0.102	-0.011	0.407**	-0.354**	0.698**	0.739**	0.83**
VWT										0.086	-0.029	0.49**	-0.591**	0.659**	0.708**	0.91**
SLN											0.352**	0.541**	0.04	0.378**	0.340**	0.04
SWD												0.674**	-0.237**	0.38**	0.233**	-0.01
TWT													-0.338**	0.81**	0.733**	0.46**
HCT														-0.296**	-0.341**	-0.756**
SYP															0.967**	0.64**
OYP																0.71**

* Significant at 5%
** significant at 1%

Table 2 Direct (on diagonal) and indirect effects of yield components on oil yield at genotypic level in 144 lines of sunflower

Characters	D50F	PDI	XLP	NUP	DMT	HDM	SGT	PHT	VWT	HCT	SLN	SWD	TWT	SYP	OCT	r(g)
D50F	0.00	-0.022	0.003	0.018	-0.112	-0.004	-0.03	-0.024	-0.045	-0.001	-0.013	0.010	0.035	0.132	0.273	0.22**
PDI	0.00	0.092	-0.007	-0.017	0.066	-0.037	0.054	0.027	0.069	0.053	-0.022	0.006	0.106	-0.760	-0.395	-0.76**
DLP	0.00	-0.07	0.009	0.025	-0.077	0.039	-0.051	-0.026	-0.071	-0.047	0.009	-0.007	-0.099	0.735	0.388	0.75**
NUP	0.00	-0.049	0.007	0.032	-0.086	0.021	-0.039	-0.023	-0.046	0.027	0.01	-0.004	-0.056	0.526	0.279	0.60**
DMT	0.00	-0.046	0.005	0.021	-0.130	0.013	-0.050	-0.031	-0.072	-0.046	-0.005	0.002	-0.019	0.434	0.414	0.48**
HDM	0.00	-0.057	0.006	0.011	-0.027	0.061	-0.045	-0.017	-0.043	-0.048	0.018	-0.015	-0.103	0.755	0.202	0.69**
SGT	0.00	-0.072	0.007	0.018	-0.096	0.04	-0.068	-0.033	-0.089	-0.082	0.01	-0.006	-0.080	0.805	0.462	0.81**
PHT	0.00	-0.065	0.006	0.019	-0.106	0.028	-0.061	-0.038	-0.089	-0.055	0.006	0.00	-0.058	0.671	0.481	0.74**
VWT	0.00	-0.058	0.006	0.014	-0.086	0.024	-0.056	-0.031	-0.108	-0.092	0.005	0.001	-0.070	0.633	0.528	0.71**
HCT	0.00	0.032	-0.003	0.006	0.039	-0.019	0.036	0.013	0.064	0.156	0.002	0.007	0.048	-0.285	-0.437	-0.34**
SLN	0.00	-0.038	0.001	0.006	0.012	0.021	-0.012	-0.004	-0.009	0.006	0.054	-0.010	-0.077	0.364	0.026	0.34**
SWD	0.00	-0.019	0.002	0.004	0.008	0.033	-0.014	0.00	0.003	-0.037	0.019	-0.028	-0.096	0.365	-0.008	0.23**
TWT	0.00	-0.068	0.006	0.013	-0.018	0.044	-0.038	-0.015	-0.053	-0.053	0.029	-0.019	-0.143	0.778	0.270	0.73**
SYP	0.00	-0.073	0.007	0.018	-0.059	0.048	-0.057	-0.026	-0.071	-0.046	0.020	-0.011	-0.116	0.961	0.373	0.96**
OCT	0.00	-0.063	0.006	0.016	-0.093	0.021	-0.055	-0.031	-0.099	-0.118	0.002	0.00	-0.067	0.619	0.579	0.71**

Residual = 0.0291; r(g) = genotypic correlation with oil yield ** Significant at 1%

D50F	:	Days to 50 per cent flowering	PDI	:	Per cent disease index (*Alternaria*)	XLP	:	Mean number of leaves/plant
NUP	:	*No. of leaves upper 1/3rd plant*	*DMT*	:	*Days to maturity*	*HDM*	:	*Head diameter (cm)*
SGT	:	Stem girth (cm)	PHT	:	Plant height (cm)	VWT	:	Volume weight (g)
HCT	:	Hull content (%)	SLN	:	Seed length (cm)	SWD	:	Seed width (cm)
TWT	:	Test weight (g)	SYP	:	Seed yield/plant	OCT	:	Oil content (%)

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Short communication

Variability and heritability for seed yield and its components in twelve genotypes of sunflower, *Helianthus annuus* L.

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Crop improvement is a continuous process which takes care of the changing needs and new problems arising in crop productivity. However to bring out any desired change existence of genetic variability is indispensable. The genetic variability has to be looked into for planning suitable measures for the crop improvement. Sunflower is a rather new crop for India where it came under cultivation only in early seventies. An attempt has been made in the present study to find out the magnitude of variability present for yield and some of the yield attributes in sunflower.

The trial comprised of 12 diverse genotypes of sunflower raised in Randomized Block Design with four replications during *rabi*, 2000-01. Each entry was sown in a plot size of 12.6 sq. m. All the recommended package of practices were followed to raise the crop.

The data were recorded on seed yield and other characters *viz.*, plant height, days to maturity, head diameter, 100 seed weight and oil content. The data were subjected to analysis of variance (Panse and Sukhatme, 1989). The phenotypic and genotypic co-efficient of variability were computed as per Burton and Devane (1953). Heritability in the broad sense was calculated as per Allard (1960), while genetic advance was worked out as per Johnson *et al.* (1955).

The analysis of variance indicated high and significant variation for all the characters under study. The PCV was greater than GCV for all the characters studied showing the environmental effect for all the characters (Table 1). The magnitude of difference between GCV and PCV was highest in the case of seed yield showing seed yield to be the character highly amenable to environmental fluctuation and manipulation. Genetic variability was also highest for seed yield. Moderate amount of genetic and phenotypic variability was observed for plant height, head diameter and 100 seed weight whereas GCV and PCV parameters were low for days to maturity and oil content. High PCV and GCV values for seed yield have been reported earlier also. Moderate amount of PCV and GCV for plant height, head diameter and low seed weight have been reported by Saravana *et al.* (1996). Ashok *et al.* (2000) also reported low PCV and GCV for days to maturity in sunflower. The high GCV found for seed yield in the present studies indicated that there exists good chance of bringing about desirable improvement in seed yield. The high PCV indicates that the seed yield character is highly input responsive. The moderate amount of GCV seen for plant height, 100 seed weight and head diameter indicates that these characters do have the potential for genetic improvement.

Table 1 Mean, range, mean sum of squares, coefficient of variability, heritability and genetic advance for seed yield and yield components in sunflower

Character	Mean	Range	Mean Sum of Squares	Coefficient of variability		Heritability Broad Sense (%)	Genetic advance as per cent of mean
				Genotypic (%)	Phenotypic (%)		
Plant height (cm)	118	78-148.6	1109.8**	13.6	15.6	76	25
Days to maturity	106	92-117	223.5**	7.0	7.1	95	15
Head diameter (cm)	11.2	7.6-16.6	9.1*	11.8	17.4	46	16
100 seed weight (g)	3.9	2.8-7.0	1.4**	13.5	19.1	50	20
Oil content (%)	43.9	37.5-49.2	23.9**	4.9	7.1	48	7
Seed yield/plant (g)	25	10-45	299.5**	25.3	33.3	58	40

** Significant at 1% level

The heritability and genetic advance estimates were interpreted as low, medium and high as per the classification of Johnson *et al.* (1955). Days to maturity and plant height showed high heritability whereas it was moderate in case of head diameter, 100 seed weight, oil content and seed yield. As heritability alone can not serve as an indication of the expected genetic improvement, the genetic advance is also taken into consideration. The present study showed high genetic advance for seed yield and plant height. It was moderate for 100 seed weight, head diameter and days to maturity and was low for oil content. Muhammad *et al.* (1992) have also reported high genetic advance for seed yield and moderate for head diameter. The character plant height had high heritability and genetic advance and as such appeared to be amenable for simple selection.

The character days to maturity appeared suitable for simple selection whereas head diameter and 100 seed weight were considerably affected by environment. Oil content with medium heritability and low genetic advance appeared to be under the influence of environment. Seed yield has moderate heritability and high genetic advance. It indicated that though the character seed yield was influenced by environment it was still amenable for simple selection as it possessed high genetic advance.

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Short communication

Combining ability for seed yield and yield components of new inbreds in sunflower, *Helianthus annuus* L.

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Combining ability analysis helps in identification of suitable parents for exploitation in breeding programmes. Studies indicate that lines good in *per se* performance, may not necessarily produce desirable types when used in crossing programmes. Hence, knowledge on combining ability of parents become more important. In the present investigation combining ability of six lines and nine testers was studied for yield characteristics in sunflower.

The experimental material comprised of 54 sunflower hybrids developed from six cytoplasmic male sterile lines belonging to four different sources of cytoplasm *viz.*, PEF, CMSI, PET-1 and PET-2 and nine testers in a line x tester mating design during early *rabi*, 2003. The hybrids were sown in Randomized Block Design with two replications along with parents during summer, 2004. Data were recorded on yield components, yield and oil content. The combining ability analysis was carried as per Kempthorne (1957). The covariance of half-sibs and full-sibs was used to obtain estimates of GCA and SCA effects and their variances.

Combining ability variance indicated significant differences among females vs. males. For males significant differences were found for days to 50% flowering, days to maturity, plant height and number of filled seeds/head and in females significant differences for days to 50% flowering and days to maturity were observed. A comparison of parents and crosses indicated that there were significant differences for seed yield and all the component characters. The relative magnitude of non-additive component was greater than additive component indicating predominance of non-additive gene action governing the characters. These results were in general agreement with earlier findings for different characters such as days to 50% flowering, head diameter and 100 seed weight (Burli *et al.*, 2001), days to maturity (Goksoy *et al.*, 2000), plant height and seed yield/plant (Radhika *et al.*, 2001), stem diameter (Burli *et al.*, 2001), number of filled seeds/head (Burli and Jadhav, 2002), seed filling (Radhika *et al.*, 1999) and oil content (Devinderpal Singh *et al.*, 1999).

GCA effects: *Gca* effects revealed that, among lines, DRSF-131B for seed yield, number of filled seeds/head and head diameter and DRSF-132B for 100 seed weight and stem diameter were good general combiners with significant positive *gca* effects (Table 1). Among the testers DRSI-165 showed significant positive *gca* effects for seed yield, number of filled seeds/head and DRSF-113R for oil content indicating good general combining ability for these characters and forms potential male parents in sunflower breeding programmes. Other male parents with significant positive *gca* effects for seed yield are DRSF-116R, R-856 and DRM 34-2R and for oil content P-356 R.

Promising cross combinations: The perusal of specific combining ability and means of cross progenies for the characters revealed that cross combinations DRSF-132A x DRSF-110R and DRSF-116A x DRSI-165 were the most promising ones for seed yield (Table 2).

From the above results it was obvious that DRSF-132A and DRSI-165 were the promising general combiners for seed yield. The cross combinations *viz.*, DRSF-132A x DRSF-110R, DRSF-116A x DRSI-165 and DRSF-109A x 3376R were promising for seed yield and can be exploited commercially.

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Table 1 General combining ability effects of seed yield and yield components of lines and testers in sunflower

Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	No. of filled seeds/ head	No. of unfilled seeds/head	Seed filling (%)	100 seed weight (g)	Seed yield/plant (g)	Oil content (%)
Lines											
DRSF-114B	-1.19**	-1.46**	-1.48	-0.11	-0.06	2.88	-11.91*	1.55*	0.01	0.74	-0.55
DRSF-116B	-0.57*	-0.52*	1.02	0.39	-0.04	-13.19	-15.23**	1.54*	-0.06	-1.02	-1.20**
DRSF-127B	-0.52*	-0.07	-13.10**	0.05	-0.12**	0.99	30.41**	-2.89**	0.18*	1.43**	1.23**
DRSF-131B	-1.35**	-0.96**	2.15	0.50	0.06	94.30**	27.60**	-0.20	0.17*	3.79**	-2.02**
DRSF-132B	0.76**	0.93**	-1.49	-0.10	0.26**	-76.79**	-11.76*	-1.69**	0.63**	-1.48**	0.54
DRSF-109B	2.87**	2.09**	12.90**	-0.74**	-0.10**	-8.19	-19.10**	1.70**	-0.59**	-3.45**	1.99**
SE,	0.22	0.21	1.81	0.21	0.04	10.93	5.52	0.62	0.07	0.54	0.32
Testers											
DRM 34-2R	-0.55*	-1.60**	-15.81**	0.27	-0.12*	-33.90*	29.23**	-3.50**	0.65**	1.81**	-1.50**
DRSF-110R	-0.46	-0.44	4.95*	-1.31**	0.06	-7.79	3.13	-0.37	-0.40**	-2.13**	-0.09
DRSF-116R	-0.05	-0.35	10.47**	0.49	-0.15**	78.46**	-11.75	3.23**	0.17	5.29**	-0.05
DRSF-113R	-1.96**	-1.35**	-7.36**	-0.20	-0.11*	-65.88**	-16.52*	0.18	-0.14	-3.56**	2.23**
DRSI-165	3.79**	5.15**	30.14**	1.20**	0.07	145.52**	20.72	1.40	-0.19*	5.94**	-1.72**
P-356R	-3.55**	-4.27**	-26.03**	-1.46**	-0.16**	-108.58**	-11.32	-2.41**	0.33**	-4.10**	1.14**
RHA-6D1	0.29	0.23	14.39**	1.60**	0.25**	-81.17**	-4.46	-1.99	0.49**	-0.57	-0.46
3376R	0.70*	0.73**	-1.63	0.19	0.05	110.89**	15.29*	3.88**	-0.64**	0.94	0.52
R-856	1.79**	1.90**	-9.11**	0.78**	0.12*	-37.55**	6.66	0.42	0.27**	3.63**	0.07
SE_t	0.27	0.26	2.21	0.25	0.05	13.38	6.76	0.76	0.01	0.66	0.39

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

Table 2 Promising crosses for seed yield and yield components in sunflower

Character	Crosses
Days to 50% flowering	DRSF-131A x R-856, DRSF-127A x DRSF-110R
Days to maturity	DRSF-116A x P-356R, DRSF-127A x P-356R
Plant height	DRSF-127A x DRSI-165, DRSF-116A x DRSF-113R
Head diameter	DRSF-116A x DRSF-116R, DRSF-132A x DRM 34-2R
Stem diameter	DRSF-127A x DRSF-116R, DRSF-132A x RHA-6D1
Number of filled seeds/head	DRSF-132A x DRSF-110R, DRSF-116A x DRSI-165
Number of unfilled seeds/head	DRSF-116A x R-856, DRSF-109A x DRM 34-2R
Seed filling (%)	DRSF-116A x R-856, DRSF-132A x DRSI-165
100 seed weight	DRSF-132A x DRM 34-2R, DRSF-116A x DRSF-113R
Seed yield	DRSF-132A x DRSF-110R, DRSF-116A x DRSI-165
Oil content	DRSF-114A x P-356R, DRSF-127A x DRSF-116R

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Short communication

Genetics of pollen colour in sunflower, *Helianthus annuus* L.*

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Inheritance studies are important both from theoretical and applied point of view. Yield levels can be stepped up by eliminating the undesirable genes and incorporating the desirable genes. The knowledge of inheritance of various qualitative characters is of paramount importance to achieve success in plant breeding. Sunflower is an important oilseed crop, which normally has yellow or yellowish pollen. The main objective of this study was to further examine the inheritance of white pollen through hybridization and to determine the genes and the manner of their action in sunflower.

The experiment was conducted at Regional Agricultural Research Station, Raichur, Karnataka for three seasons during 2003-04. Manual hybridization was made in field between parents having different pollen colours, *viz.*, WSWS-8 (yellow) x WSNB-17 (white) and WPNB-17 (white) x WSWS-8 (yellow). Plants of two crosses were harvested separately after maturity. The hybrid seeds of two crosses were sown in early summer, 2004 to raise F_1 generation. Before flowering, all the individual plants were bagged to self and to prevent open pollination. After flowering, the number of both white and yellow pollen plants was recorded in each cross. F_2 generation was raised with 1345 plants from the cross WSWS-8 (yellow) x WPNB-17 (white) and 1270 plants from the cross WPNB-17 (white) x WSWS-8 (yellow). After complete flower opening in number of plants showing white and yellow pollen was recorded in each cross. The data of the F_2 segregation was tested using chi-square test.

The results obtained from both direct and reciprocal crosses revealed that all the F_1 plants had yellow pollen grains and none of the F_1 plants had white pollen (Table 1). Apart from the two pollen colours, no other pollen colour could be found. Continues or intermediate variation was not found in pollen colour in the F_1 generation, compared with their parents. This is a typical feature of qualitatively inherited character and of full dominance over recessiveness. Hence it could be concluded that white pollen is recessive to yellow pollen, and white pollen is expressed only when the genotype is homozygous.

The pollen colours of F_2 generation for two crosses were recorded during field observations. Among 1345 F_2 plants in cross WSWS-8 (yellow) x WPNB-17 (white), 999 had yellow pollen, whereas the remaining 346 plants had white pollen. The F_2 plants of cross WPNB-17 (white) x WSWS-8 (yellow) totaled 1270 with 962 having yellow pollen and 308 having white pollen. The segregating ratio of yellow pollen to white pollen plants were approximated to 3:1 respectively for the two crosses.

Table 1 Phenotypic segregation for pollen colour in F_1 and F_2 generations of the crosses WSWS-8 x WPNB-17 and WPNB-17 x WSWS-8 in sunflower

Cross	Character	F_1	Obs/Exp	F_2 generations		Ratio	χ^2	P-value
				Yellow	White			
WSWS-8 x WPNB-17	Pollen	Yellows	Obs	999.00	346.00	3:1	0.5262	0.5-0.3
(Yello. pollen) (White pollen)	Colour	Pollen	Exp	1010.50	334.50			
WPNB-17 x WSWS-8	Pollen	Yellow	Obs	962.00	308.00	3:1	0.3405	0.7-0.5
(White pollen) (Yellow pollen)	Colour	Pollen	Exp	953.00	317.00			

Obs = Observed frequency; Exp = Expected frequency and P-value = probability value

* Part of the Thesis submitted to the University of Agricultural Sciences, Dharwad by the first author.

Majority of the sunflower genotypes have yellow pollen with genotype 'PP' whereas white pollen have genotype 'pp'. When white and yellow pollen plants are crossed, they form genotype 'Pp', which also showed yellow pollen, because recessive gene 'p' is concealed by dominant gene 'p'. Thus, white pollen is controlled by a pair of recessive genes 'pp' and this character is expressed only when the recessive genes are in homozygous condition. Genotypes 'PP' or 'Pp' will have yellow pollen colour, while the genotype 'pp' will have white pollen.

Qiao *et al.* (1992), Qiao *et al.* (1993) and Wang and Wang (1994) reported that yellow pollen was dominant over white pollen and controlled by a pair of single genes. The results obtained from the present study are in agreement with the previous reports. The white pollen sunflower helps to enrich the gene pool of sunflower germplasm and might have special importance in sunflower breeding programme, it acts as very good gene marker in detecting admixtures and contaminants in sunflower hybrid seed production.

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Short communication

Stability analysis of sunflower, *Helianthus annuus* L. genotypes for their performance under different rainfall pattern

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Sunflower is a versatile crop. Its adaptability to a wide range of soil and climatic conditions are the oft-cited phenomenon which make its cultivation possible during any part of the year in the tropical and sub tropical regions of the country (Reddy and Kumar, 1985). The crop is considered thermo and photo insensitive (Kavi *et al.*, 1994) but rainfall is the most powerful among all the weather elements during the rainy season. The crop responses are greatly modified by the pattern of rainfall distribution and exposure of the crop during the rainy period to match with the critical periods of water requirement. The optimum date of sowing of the crop is to be identified as to trace out the range during which it is stable in yielding ability. Hence, this experiment was conducted.

The experiment was conducted in the sandy loam soil at the College Farm, College of Agriculture, Rajendranagar during *kharif*, 2003. The soil was well drained. It had slightly alkaline reaction with a pH of 7.46. The Electrical Conductivity was 0.17 dS/m. Its fertility status was estimated to have low available N of 169 kg /ha, medium available P_2O_5 of 32 kg/ha and high available K_2O of 287 kg/ha. There was a total rainfall of 800 mm during the *kharif* season.

The lay out of trial was a Randomized Block Design. There were 10 treatments which included the test performance of two genotypes Morden and Jwalamukhi sown on 25 June, 5 July, 15 July, 25 July and 4 August. There were *four replications. The crop was fertilized with 30 kg N/ha,* 60 kg P_2O_5/ha and 30 kg K_2O/ha at the time of sowing and top dressed with 30 kg/ha after one month. The seed yield data were scrutinized to assess the stability of two genotypes by adopting the procedure outlined by Eberhart and Russel (1966). Analysis of variance of stability for seed yield that Genotype x environment interaction was tested against pooled error, which satisfied the requirement of stability analysis (Table 1, 1a). According to Eberhart and Russel (1966) an ideal variety is the one which has mean performance, average responsiveness (b=1) and high stability (s^2d_i=0).

The seed yield of Jwalamukhi was 1250 kg/ha. Morden yielded 1069 kg/ha. Jwalamukhi is a long duration hybrid maturing in 110 days compared to the variety Morden which matured in 95 days. The longer duration of the hybrid was exposed for more photosynthetic assimilation. These results further indicate that the performance of two genotypes was significantly influenced by variable environment due to different dates of sowing. The interaction of genotypic responses with the environment also highly significant. The positive environment indices revealed that the sunflower respond to produce higher yield if sown between 25 June and 5 July. The environmental indices recorded a negative impact by later sowings from 15 July up to 4 August.

Table 1 Analysis of variance of genotype x environment interaction

Source	d.f.	Sum of squares	Mean sum of squares
Varieties	1	82437	82437**
Env.+(var*Env)	8	444899	55612*
Var*Env (linear)	1	3275	325**
Env. (Linear)	1	439506	439506**
Pooled deviation	6	2118	353
Pooled error	30	27753	925
Total	9	527336	58592

Table 1a Stability parameters showing the response of sunflower genotype Jwalamukhi and Morden to environmental variations

Genotype	Stability parameters		
	Mean ($\bar{x}$)	Regression coefficient (b_i)	Standard deviation (Sd_i)
Morden	1069	0.91	-5.71
Jwalamukhi	1251	1.08	-5.72

These yield response patterns are best explained by the rainfall distribution during different stages of crop growth (Table 2). There was an acute shortfall of rain during the crucial bud and flowering stages which occurred 45 and 60 DAS when sunflower was sown late on 15 or 25 July and 4 August. The crop sown on 25 June received a rainfall of

135.2 mm during this crucial water requirement period distributed in 5 rainy days. The crop sown on 5 July was also well supplied with water through 125.4 mm rainfall in 5 rainy days. The rainfall was also well distributed during the crop establishment stage up to 15 days seedling stage at 15 to 30 days and stem elongation to bud formation stage during 30-45 DAS. The regression coefficient of 0.91 for Morden and 1.08 for Jwalamukhi were not significantly different from unity. This indicates the ready responsiveness of crop to favourable weather governed by continued and well distributed rainfall during the crop period. But the high magnitude of standard deviation established the inconsistent performance of sunflower genotypes and high sensitivity to moisture limitation during the bud formation and flowering phases. These results thereby indicate that sunflower is highly adaptable to various climatic conditions chiefly influenced by the pattern of rainfall distribution, while the two genotypes are not stable in performance to rainfall aberrations. The crop should be sown early with the onset of monsoon and latest by 5 July to harness higher yield. The choice of genotype favoured Jwalamukhi which occupies the land by additional 20 days over Morden, but in practice the seed of Morden is very cheap and locally multiplied by the farmers for repeated use unlike hybrid.

Table 2 : **Rainfall (mm) pattern, number of rainy days and environmental index during the crop growth period of sunflower**

Dates of sowing	Environmental index	Days after sowing											
		0-15		15-30		30-45		45-60		60-75		75-90	
		Total rainfall (mm)	Rainy days	Total rainfall (mm)	Rainy days	Total rainfall (mm)	Rainy days	Total rainfall (mm)	Rainy days	Total rainfall (mm)	Rainy days	Total rainfall (mm)	Rainy days
25th June	231	56.9	3	148.9	11	148.6	7	135.2	5	16.4	2	18.6	0
5th July	226	217.4	7	125.8	8	120.0	5	120.4	5	6.8	1	36.2	3
15th July	-237	151.4	9	161.6	8	120.4	5	6.2	1	36.0	3	24.5	2
25th July	-155	148.6	6	135.2	6	16.4	2	7.2	1	49.0	4	53.7	3
4th Aug.	-300	120.0	6	126.4	4	6.8	1	37.2	3	24.5	1	98.4	5

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Short communication

Efficacy of biofertilizers in rainfed sunflower, *Helianthus annuus* L. production

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Sunflower is an important oilseed crop in India. It is said to be an exhaustive crop. Application of chemical fertilizers to soil, besides being expensive, often results in imbalance in soil reserve. In view of the escalating costs and high demand-supply gap of chemical fertilizer, there is a strong need to find cheap and non-renewable alternate resource through suitable biofertilizers; the application of which is one of the technologies in modern agriculture. These microbial inoculants have attained special significance in recent times. These are low cost, non bulky agricultural inputs which could play a significant role in plant nutrition as a supplementary/complementary factor. Use of microbial inoculants such as *Azospirillum* (Ram *et al.*, 1992) and *Azotobacter* can increase the crop yields while contributing towards soil health and sustainability of agriculture. Hence, the present study was undertaken to assess the effect of biofertilizers for rainfed sunflower production and also to find out the economy in chemical N fertilization.

Field experiments were conducted during *Kharif* seasons of 2000, 2001 and 2002 on clayey soil under rainfed conditions at Regional Agricultural Research Station, Nandyal. The soil was slightly alkaline (pH 8.2), low in organic carbon (0.52%) and available nitrogen (206.32 kg/ha), medium in available phosphorus (33.4 kg P_2O_5/ha) and high in available potassium (291 kg K_2O/ha). The experiment was laid out in randomized block design with three replications and 12 treatments (Table 1). Sunflower hybrid KBSH-1 was sown with a spacing of 60 cm x 30 cm. Fertilizers was applied as per the treatments. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash respectively. Seed inoculation was done with *Azospirillum/Azotobacter* at 50 g/kg of seed before sowing. The mixture of 50g of *Azospirillum/Azotobacter* culture plus 150 ml starch was added to 1 kg seed and mixed thoroughly. After mixing, the uniformly coated seeds were dried under shade. All the treatments received a uniform dose of 60 kg P_2O_5/ha and 30 kg K_2O/ha. The dose of phosphorus and potassium were applied as basal dose. Urea was however applied in three splits - half as basal and the remaining half applied in two splits at 30-35 DAS and 50-55 DAS. Data on yield attributes, seed yield, oil yield was recorded in respective years and economics and benefit cost ratio were worked out on the basis of the pooled mean for seed yield over the years. Mean data of three years were used for interpretation of results.

Table 1 Effect of bio-fertilizers on yield attributes, seed yield, oil content, oil yield and economics of rainfed sunflower (Pooled mean over three years, 2001 to 2003)

Treatment	Head diameter (cm)	No. of filled seeds/ head	Seed yield (kg/ha)				Oil content (%)	Oil yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
			2001	2002	2003	Pooled mean					
No nitrogen (control)	11	513	878	631	743	751	36.0	272	12016	5961	1.98
50% N	11	626	894	1041	855	930	36.4	337	14880	8530	2.34
100% N	12	652	1052	1366	1089	1169	38.4	447	18704	12061	2.82
Azospirillum seed treatment	11	626	712	1186	772	890	38.0	336	14240	8135	2.33
Azotobacter seed treatment	12	638	808	1306	658	924	37.3	343	14784	8679	2.42
Azospirillum + *Azotobacter* seed treatment	12	623	730	1158	900	929	37.9	350	14864	8709	2.41
50% N + *Azospirillum* seed treatment	12	636	1029	1265	997	1097	37.9	416	17552	11152	2.76
50% N + *Azotobacter* seed treatment	12	639	1000	1343	916	1086	39.4	427	17376	10976	2.74
50% N + *Azotobacter* seed treatment	12	655	848	1342	1016	1069	38.5	384	17104	10654	2.65
SEm±	0.3	30	46	36	64	79	1.1	25			
CD (P=0.05)	NS	91	139	108	195	237	NS	73			

Yield attributes and seed yield: *Except control (no* nitrogen) all the other treatments recorded significantly higher and similar number of filled seeds/head. Head diameter of sunflower was not influenced either by nitrogen or biofertilizer treatments (Table 1). Seed inoculation of biofertilizers alone could not influence the seed yield of sunflower and was at par with control. Application of recommended inorganic N recorded significantly highest seed yield of sunflower compared to control (no nitrogen), 50% N application and seed inoculation with either *Azospirillum* alone or *Azotobacter* alone or both; and was on par with use of 50% recommended N along with inoculation of *Azospirillum* and *Azotobacter* singly or together (Table 1). This assumes that seed inoculation with biofertilizers either alone or in combination could result in absolute saving of 50% nitrogen. Saving of 25% inorganic N by seed inoculation with biofertilizer was reported by Pragathi Kumari *et al.* (2004) in sunflower and Khadse *et al.* (1991) in safflower.

Oil content and oil yield: The seed oil content was not influenced by different biofertilizer treatments. However, the oil yield was in accordance with the seed yield. Seed inoculation of biofertilizers with *Azospirillum* combined with 50% N resulted in significantly higher oil yield than in other treatments (Table 1). The next best superior treatments in giving higher oil yield were application of 50% N + *Azotobacter* and 50% N + *Azospirillum* + *Azotobacter* seed inoculation. The effect of these treatments was same as that of 100% inorganic N application. Higher seed yield produced in those treatments as influenced by biofertilizers might be the reason for higher oil yield than in control (no N). The treatments involving biofertilizer inoculation alone or 50% N application resulted in similar oil yield as that of control. These results were in accordance with Amruthavalli and Reddy (2000).

Economics: The gross and net monetary returns and B:C ratio with application of recommended inorganic N, use of 50% N in conjunction with either *Azospirillum* or *Azotobacter* or both for seed treatment were similar and higher than that of use of biofertilizers for seed treatment either alone or in combination, use of 50% N alone and non-use of N (Table 1). This might be due to higher seed yield obtained in these respective treatments. This clearly indicates that in sunflower crop inoculation of biofertilizers (either *Azospirillum* or *Azotobacter* or their combination) along with 50% recommended N could have reduced the requirement of inorganic nitrogen by 50% to the extent supplemented by biofertilizers. It may also be noted that the biofertilizers cost is almost pronounced on the seed yield as that of 100% inorganic nitrogen, thereby saving 50% nitrogen cost without any reduction in seed yield is possible. These findings are in accordance with Karunakaran and Palaniappan (1989).

Thus, seed inoculation with *Azospirillum* or *Azotobacter* or both could effectively substitute 50% N needs of rainfed sunflower.

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Short communication

Influence of variations in growing degree-days on performance of sunflower, *Helianthus annuus* L.

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Sunflower is widely grown during any part of year in the Deccan Plateau. It has become an alternate crop to rice mainly due to its extremely low water requirement and short duration. The shrinking groundwater table poses severe threat of declining water availability to support long duration and high water requirement crops. Although sunflower suits better to grow with less water availability and less number of irrigations, its yield potential is also largely influenced by the prevailing weather. Therefore, it is essential that the crop should be sown at an optimum time when weather parameters are most favourable and the groundwater resource is best exploited that match well with the crop water requirement for maximum production. Hence, this experiment was conducted to elicit information on the optimum time of sowing sunflower during post rainy season in the agro ecological situations of Southern Telangana Zone in Andhra Pradesh.

A field experiment was conducted during *rabi*, 2002-03 at the Agricultural College Farm, Rajendranagar, Hyderabad. The soil was sandy loam in texture. It was slightly alkaline with 7.7 pH. The electric conductivity was low (0.16 dS/m). It had a low organic carbon content of 0.39 % and a low quantity of 176 kg available N/ha. It was rich both in available phosphorus (32.6 kg P_2O_5/ha) and potassium (287.5 kg K_2O/ha). The layout of the experiment was a Randomized Block Design. Two genotypes of sunflower *viz.*, Morden and Jwalamukhi were sown at 5 dates with 10 days interval from 20 November to 30 December. Ten treatments were grown in plots of 6 x 4.5 m and replicated four times. The ancillary observations and yield data were statistically evaluated through the two variable factorial analysis. The accumulated heat units were worked as growing degree days (GDD).

$$GDD = \frac{T_{max} + T_{min}}{2} - T_b$$

Where,

T_{max} = Maximum temperature of the day (°C)

T_{min} = Minimum temperature of the day (°C)

T_b = Base temperature (10°C) (Murthy,2002)

The genotypes of sunflower *viz.*, Morden and Jwalamukhi recorded considerable differences in the vegetative crop growth, yield components and yield due to different sowing dates (Table 1). Sunflower is known to respond differentially to differences in temperature during the crop growth period. This weather parameter is known to have a significant impact as the most important among the different weather elements during the post rainy period (Yadav and Singh 1975; Smith *et al.*, 1978; Habeebullah *et al.*, 1983). Among the two genotypes, Jwalamukhi attained a significantly tall height, produced more number of leaves and dry matter/plant than Morden. This may be due to the hybrid vigour of Jwalamukhi. The robust growth with a larger photosynthetic apparatus of leaves probably helped the hybrid to accumulate significantly more number of total and filled seeds/capitulum. The higher percentage of seed filling in the hybrid probably owes to the little autogamous nature of the disc florets of the hybrid in this highly cross pollinated crop (Andrade, 1993; Nandagopal *et al.*, 1995; Bharud and Patil, 1996). The significant yield increase in Jwalamukhi (1663 kg/ha) was therefore the outcome of increase in number of seeds with higher percentage of filling compared to Morden. Significant increase in the stalk yield of Jwalamukhi over Morden was mainly due to the consequence of profuse vegetative growth.

The growth and yield responses were modified by a change in the weather parameters prevailing during the crop growth period due to a change in the sowing time. Relatively less number of heat units was recorded by the crop sown on 20 November. The crop showed an optimum response of its vegetative growth. The mean plant height, number of leaves and drymatter/plant reduced by delaying the sowing upto 10 December and subsequently then after at 10 days interval until 30 December. The crop seemed to be more sensitive to the increase in accumulated heat units during the reproductive phase. There was a significant reduction in the number of total and filled seeds/capitulum and filling percentage of seed per unit delay of sowing by 10 days from 20 November until 30 December (Bange *et al.*, 1997). The crop sown on 20

November produced mean seed yield of 1724 kg/ha. It reduced significantly with successive delay in sowing by 10 days until 30 December. *The yield of stalks was also* reduced in the same chronology. As the heat units increased with delayed sowings the duration of the two sunflower genotypes reduced sharply. Hence, the less exposure time of the crop to sunlight for photosynthetic utilization had a limiting effect on the crop growth, yield *components and yield. The study indicated* that the accumulated heat units during the crop growth period of sunflower match best to reach a better harvest by sowing the crop on 20 November.

Table 1 Growth, yield and yield attributes of sunflower genotypes as influenced by dates of sowing

Treatment	Plant height (cm)	No. of leaves/plant	Dry matter (g plant^{-1})	No. of filled seeds per capitulum	Filling percentage	Test weight (g)	Seed yield (kg /ha)	Stalk yield (kg /ha)
Genotype								
Morden	90	21	75.6	629	86.8	38.79	1195	2324
Jwalamukhi	155	25	88.8	814	90.8	39.50	1663	2886
SEm±	0.8	0.37	1.1	6.1	0.23	0.78	8	12
CD (P=0.05)	1.7	0.76	2.2	12.5	0.47	NS	16	24
Date								
20th November	127	24	91.4	850	93.0	43.72	1724	2874
30th November	126	23	90.0	807	91.5	42.81	1585	2755
10th December	121	22	83.4	723	89.3	37.61	1401	2576
20th December	119	22	78.0	657	87.2	37.44	1305	2495
30th December	117	21	68.2	568	83.0	34.13	1129	2325
SEm±	1.3	0.58	1.7	9.6	0.37	1.24	12	19
CD (P=0.05)	2.6	1.19	3.4	19.8	0.75	2.54	25	38
Interaction								
SEm±	1.8	0.82	2.4	13.6	0.52	1.75	17	26
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

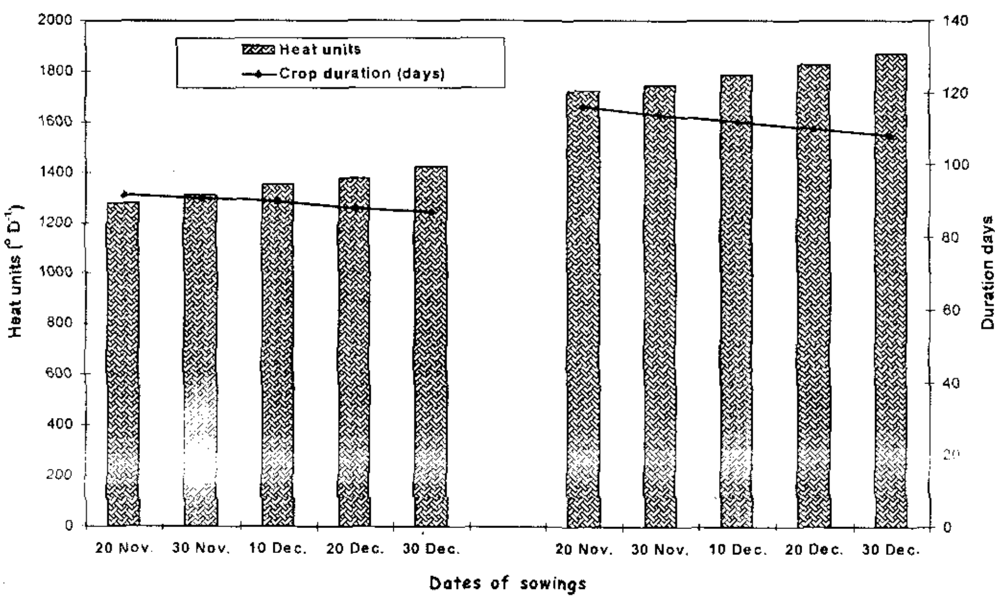

Fig. 1 Accumulated growing degree day and days for sunflower genotypes under different sowings

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Short communication

Meteorological interventions through sowing dates adjustment on the performance of sunflower *(Helianthus annuus* L.) in *kharif* season

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Sunflower is a handy crop for farmers owing to its versatile nature of cultivation throughout the year. In Andhra Pradesh it is grown on an area of 2.8 lakh ha with a production of 0.28 Mt. The performance of this crop is remarkably different from location to location, between seasons, within location and time of sowing within a season (Habeebullah *et al.*, 1983). This phenomenon warrants best yield exploitation by adjusting the time of sowing at a time when the weather parameters are most congenial. The selection of cultivar for particular sowing time is also an important factor for adoption by the farmers. Hence, an experiment was conducted to explore the feasibility of sowing of sunflower genotypes over a range of intervals during the rainy season in the Southern Telangana Zone of Andhra Pradesh.

The experiment was conducted in the sandy loam soil at the Farm, College of Agriculture, Rajendranagar during *kharif*, 2003. The soil had a pH of 7.46 and EC of 0.17 dS/m. It had a poor organic status of 0.34% and low level of 168.8 kg /ha available nitrogen. The available phosphorus was medium in status with available P_2O_5 31.87 kg/ha. The potassium status was rich with available K_2O content of 280 kg/ ha. The layout of experiment was Randomized Block Design. The treatments included two genotypes namely Morden and Jwalamukhi sown at 10 days interval commencing from 25 June to 4 August 2003. The plot size was 6 x 4.5 m with spacing of 45 cm between the rows and 30 cm between the plants. Fertilizers were applied to supply 30 kg/ha N at the time of sowing followed by a top dressing of 30 kg N/ha at 45 days age of crop. The data on crop growth, yield components and yield were statistically analyzed following the factorial concept.

The results recorded substantial variation both due to the choice of genotype and date of sowing on the performance of sunflower. The hybrid Jwalamukhi had more vigorous vegetative growth (Table 1). Nanda Gopal *et al.*, 1995; and Subba Reddy *et al.*, 2000 also reported that the hybrids are vigorous to grow than the cultivars.

Table 1 Influence of dates of sowing and genotypes on vegetative growth of sunflower

Treatment	Plant height (cm)	Internodal length (cm)	No. of leaves	Leaf area (cm^2)	Leaf length (cm)	Leaf width (cm)	Drymatter
Genotype							
Morden	84	7.3	17	4726	19	21	74.9
Jwalamukhi	125	7.8	19	5640	20	21	81.2
SEm±	3.1	0.2	0.3	139	0.27	0.39	1.3
CD (P=0.05)	6	0.5	0.6	404	NS	NS	2.59
Date							
25th June	107	8.3	16	3225	16	19	76.9
5th July	115	8.7	19	6972	23	24	87.2
15th July	100	6.8	16	4081	18	19	74.3
25th July	99	7.1	19	5625	20	22	75.5
4th August	103	7.0	20	6010	20	22	76.3
SEm±	4.8	0.4	0.5	220	0.43	0.62	2.0
CD (P=0.05)	10.0	0.8	1.0	639	0.89	1.28	4.10
Interaction							
SEm±	6.92	0.53	0.70	311	0.62	0.88	2.82
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Jwalamukhi attained a significantly tall height (125.1cm) with larger length of inter nodes (7.8 cm) and produced more number of leaves (19) and larger area/plant (5640 cm). Thereby it accumulated more dry matter/plant (81.2 g) than Morden. Sunflower sown on 5 July had a good vegetative growth. There was a significant difference in plant height, length of internodes and number of leaves/plant on 25 June, but the crop displayed remarkably less area/plant. This was probably due to the slow growth of leaves as indicated by substantial reduction in the leaf length and width. All the growth parameters reduced by delayed sowing on 15 or 25 July and 4 August.

Jwalamukhi produced bigger flower heads with more number of seeds/capitulum, but test weight was significantly less compared to Morden. Consequent to the large number of seeds/capitulum, Jwalamukhi produced significantly more yield of 1250 kg/ha compared to Morden which produced 1069 kg seed/ha (Table 2). Owing to the rank vegetative growth in response to the hybrid vigour, Jwalamukhi produced significantly more yield of stalks.

Due to changing weather variables, different sowing dates also altered the yield components and yield of the crop significantly. Sunflower sown on 25 June and 5 July recorded a better reproductive growth than the late sowings. Capitulum diameter, number of filled seeds/capitulum, test weight and eventually the seed yield got reduced significantly by sowing the crop on 15 July. The seed and stalk yield reduced sharply with further delay in sowing time until 4 August. These results indicted that sunflower should be sown early before 5 July to harvest maximum produce.

Among the weather variables, rainfall alone is the most decisive element to influence the crop performance in the rainy season. The yield is markedly influenced by the uniform distribution pattern of rainfall (Fig. 1). The ideal crop performance with high yield on 25 June and 5 July was mainly due to the good rainfall distribution consistently from sowing until 60 days which coincided with the flowering and pollination resulted in optimum moisture availability during these stages and also there was no severe moisture limitation during the subsequent stages, but the crop sown on 15 and 25 July received a very low rainfall of only 6.2 and 7.2 mm during the critical stags of bud formation until flowering from 45 to 60 days after sowing. The subsequent low rainfall was perhaps inadequate to compensate the shock of moisture stress during bud formation and flowering of crop. Moisture stress deficit initiated early by 30 days during the vegetative growth of the crop sown on 4 August. There were little showers during the most crucial reproductive stage of bud formation until maturity. Hence the yield was low when the crop was sown in August. Rawson and Hindmarsh, 1982 also emphasized that the crop should not be starved of moisture during the flowering stage. Considering this rainfall pattern sunflower sown on 25 June and 5 July seem to provide good yield than the delayed sowings. Nanda Gopal *et al.* (1985) and Chavan *et al.*, (1990) also reported that the crop sown early with the onset of monsoon yielded more than the late sowings. Jwalamukhi is more productive than Morden but mature late in 110 days compared to Morden which mature by 90 days.

Table 2 Influence of dates of sowing on yield and yield attributes of sunflower

Treatment	Capitulum diameter (cm)	No. of filled seeds/ capitulum	Test weight (g)	Seed yield (kg /ha)	Stalk yield (kg /ha)
Genotype					
Morden	9.7	660	43.8	1069	3209
Jwalamukhi	11.0	703	39.9	1251	3492
SEm±	0.29	10	0.6	20	46
CD (P=0.05)	0.60	21.66	1.16	41	93
Date					
25th June	11.72	746	44.8	1392	3536
5th July	12.68	754	45.5	1387	4043
15th July	9.63	677	41.2	1157	3263
25th July	8.98	602	40.1	1005	3071
4th August	8.93	602	37.7	859	2840
SEm±	0.46	16.69	0.89	31	72
CD (P=0.05)	0.95	34.26	1.84	65	148

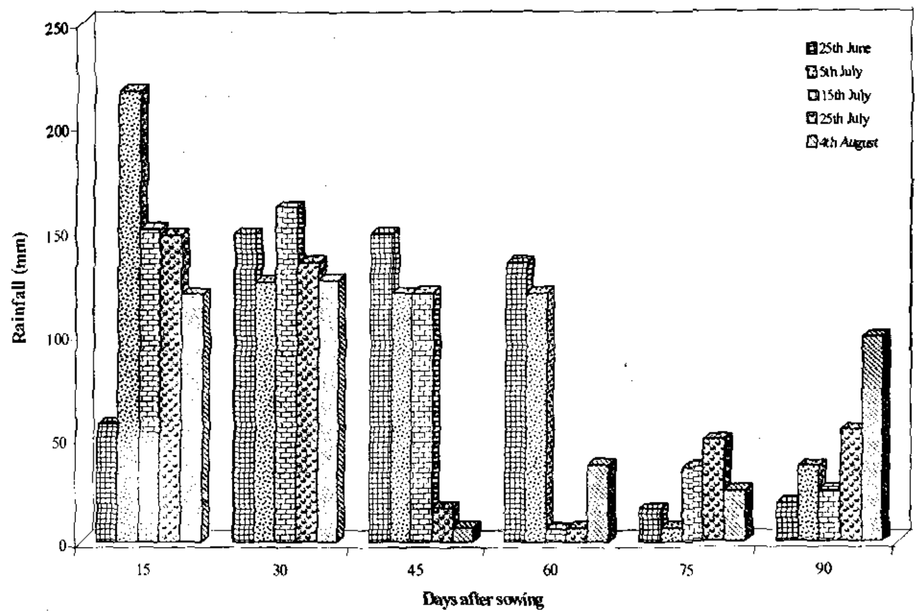

Fig. 1 : Rainfall pattern during the crop growth period of sunflower

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Short communication

Effect of different levels of phosphorus and sulphur on the growth, yield and oil content of sunflower, *Helianthus annuus* L.

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Sunflower has been proved to be a highly promising crop in the different agro-climatic conditions of India. Phosphorus is one of the essential nutrient for plant growth. In acute deficiency of phosphorus flowering and seed formation is greatly reduced, resulting in poor yield and oil content. Sulphur is also essential nutrient for plant growth. Sulphur fertilization to sunflower showed great promise in promoting seed and oil yields as well as its quality. The deficiency of sulphur causes accumulation of nitrate, amides and carbohydrates which retard the formation of proteins (Tandon, 1989). The present studies were aimed to find the role of phosphorus and sulphur on the productivity of sunflower.

A field experiment was conducted at Crop Research Farm of Agronomy Department, Allahabad Agricultural Institute, Allahabad during *kharif*, 2002. The soil had silty loam texture with pH 7.6 and contained 0.21% organic carbon, available nitrogen 78 kg/ha, phosphorus 5.9 kg/ha, potassium 37.7 kg/ha and S 9 ppm. The three levels of phosphorus (0, 30, 60 kg/ha) and three levels of sulphur (0, 15, 30 kg/ha) were tested in a Randomized Block Design with three replications. An uniform application of nitrogen at 60 kg/ha and potash at 50 kg/ha along half quantity of nitrogen full phosphorus and potash and sulphur was applied through basal application at the time of sowing rest of the nitrogen was top dressed in two splits at 25 days and remaining half of nitrogen at 50 days after sowing. Seeds were sown in rows at a spacing of 60 cm x 25 cm between row and plants. Standard crop management practices were adopted to grow good crop of sunflower. Oil content was estimated by extracting the oil in Soxhlet's apparatus.

The growth, yield and oil content of sunflower increased significantly with each increment of P upto the level of 60 kg/ha. This was expected because the soil of the experimental area was low in available P. Phosphorus positively influenced the head diameter and test weight also. Chianiara *et al.* (1989) and Krishnamurthy and Mathan (1996) also reported similar results.

Table 1 Effect of phosphorus and sulphur on the growth, yield and oil content of sunflower

Phosphorus level (kg/ha)	Plant height (cm)	Stem girth (cm)	Seed yield (kg/ha)	Test weight (g)	Head diameter (cm)	Oil (%)
0	124	4.23	2225	43.60	16.4	35.4
30	132	4.96	2369	45.53	21.2	37.5
60	139	6.14	2740	48.84	22.6	39.2
SEm±	0.29	0.06	65	0.12	0.3	0.1
CD (P=0.05)	0.63	0.14	139	0.25	0.6	0.3
Sulphur levels (kg/ha)						
0	130.80	5.03	2384	44.80	19.7	37.3
15	131.78	5.13	2452	45.50	20.1	37.3
30	132.37	5.17	2497	47.70	20.4	37.5
SEm±	0.296	0.06	65	0.12	0.3	-
CD (P=0.05)	0.628	0.14	139	0.25	0.6	-

The growth and yield attributing characters significantly increased with the increasing levels of sulphur. This was expected because the soil of the experimental area was low in available S (8 ppm). Higher seed yield and oil content obtained under 30 kg/ha sulphur. Beneficial effect of S on sunflower productivity has also been reported by Reddy *et al.* (1996).

The results of this experiment showed that the growth attributing characters of sunflower *viz.*, plant height and stem girth increased with levels of increasing phosphorus 60 kg/ha and sulphur 30 kg/ha. Higher seed yield and oil content were observed under highest dose of phosphorus (60 kg/ha) and sulphur (30 kg/ha).

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Short communication

Phosphorus requirement and use efficiency by sunflower, *Helianthus annuus* L. in P-accumulated vertisols

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Crop utilisation of applied fertilizer phosphorus is generally low due to sorption and precipitation reactions in soils. Consequently, a large accumulation of phosphorus takes place over the years, particularly in the soils that receive regular and liberal rates of P applied to each crop in a cropping system. The long-term fertilization experiments conducted across the country have clearly demonstrated the accumulation of phosphorus in the soils of different types, inspite of using recommended fertilizer doses (Nambiar, 1994). This is mainly because the applied P is usually fixed very quickly and is being retained in the top layers of the soil leading to slow and steady saturation of P-fixation sites on the soil. The residual P accumulated from previous additions can influence not only speciation and availability of P but also the availability of other nutrients. Under these circumstances, it is necessary to ascertain the requirement of P on such soils to crops not only to reduce the cost of chemical P fertilizer input from the current level of general recommendation but also to avoid any nutritional imbalances that might arise due to excess P availability (e.g. zinc). P accumulation in soils is also a matter of environmental concern because of possibility of eutrophication of water bodies due to loss of P from top soil into water. Therefore, an initial investigation is planned to find out the requirement of P to sunflower crop in P-accumulated soils belonging to vertisol order using P-32 radiosotope along with its use efficiency as influenced by higher P fertility of the soil.

Two soils belonging to vertisols with medium and high available P were used in this investigation. Bulk soil samples were collected from rice fields located at Agricultural Research Institute, Rajendranagar, Hyderabad wherein sunflower is also often grown as a sequence crop. The initial characteristics of these medium and high P soils respectively as determined following standard procedures (Tandon, 1993) were: pH 8.1 and 8.2; EC-0.24 and 0.22 dS/m; Olsen's P-40 and 62 kg P_2O_5/ha; clay content 60 and 65%; DTPA zinc-0.92 and 1.34 mg/kg and P fixation capacity-66 and 47% (Waugyh and Fitts, 1966). Bulk processed soil of seven kg each was filled in porcelain pots measuring about 100 cm in diameter and 25 cm in depth. Five levels of phosphorus *viz.*, 100, 75, 50, 25 and 0% of recommended dose of P for sunflower (RDP-50 kg P_2O_5/ha) were imposed as treatments. Sunflower cv. APSH-11 was raised during *rabi*, 2002-03. Phosphorus as per treatment was supplied through DAP and rest of the N and K were supplied uniformity to all the treatment pots in the form of urea and muriate of potash, respectively. The P in DAP was tagged with ^{32}P radioisotope @ 11.1 Mbq (0.3 mCi)/g P_2O_5. The treatments were replicated thrice and the crop was harvested at flowering stage. Radioassay of ^{32}P in plant samples was carried out using GM counter (Model RCS 4027A) as per the procedures laid out by IAEA (1990).

The drymatter yield of sunflower as influenced by P fertilizer application in varied P-accumulated soils is presented in Table 1. The mean yield of the crop was highest (28.8 g/pot) when 100% recommended dose of P was supplied to the crop but at the same time was found to be on par with the application of 75% RDP to the crop. It appears that the recommended dose of P to sunflower crop under nethouse conditions can be reduced by 25% without sacrificing the yields in P accumulated soils. But, perusal of the same data indicates that the extent of drymatter of yield of the crop is significantly higher with higher soil P fertility status when compared to that of medium P soil as much as by about 33%. The interaction effect of initial soil P status and fertilizer P levels also indicate that the yield level that could be achievable with 100% RDP application to medium P soil (25.3%) can be obtained in high P soil with a nominal application of 25% of RDP to the same crop and thus saving 75% of cost of P input in high P soil. These observations point out that there is a possibility of reducing the recommended dose of P fertilizer to sunflower crop on soils with higher initial available P provided higher yields than what is achievable in medium soils is not sought. These findings under controlled conditions need to be field verified for ultimate recommendations. The results of these findings also corroborate earlier findings of Surendra Babu *et al.* (2004) who have reported increased crop yields in high P Vertisols and the implications of such observation on saving of input P cost *vis-a-vis* higher yields that are possible in such soils. They have also indicated the possible limitation of zinc availability to crop in high P fertile soil hindering the potential production. However, in this study no deficiency of zinc in the crop was noticed as the soil used in the experiment received the zinc fertilizer in the earlier rice crop.

The P content in the plants at flowering stage was in adequate quantities in all the treatments as the soils used were having adequate P availability. The increased fertilizer P application and higher P fertility of soils resulted in higher P content in the plants (Table 1). The total phosphorus uptake by sunflower plants was also significantly affected by both the levels of fertilizer application and soil P fertility status. The total P uptake by the crop was higher when raised on high P soils to an extent of 56 per cent because of higher yields recorded in this soil coupled with greater concentration of P in the plants when compared to that of medium P soil. Thus, there is a tendency of higher removal of P by the crop from high P soils through high yields to a greater extent. This observation points out that there is a need to monitor soils with high P fertility more frequently through soil testing for deciding either to reduce the P input (cost) or to sustain the levels of P in soils for higher productivity when compared to normal soils deficient in available P.

The radioassay data for different P fertilizer parameters are presented in Table 2.

Table 1 **Effect of initial soil available and fertilizer P application on drymatter yield, P content and P uptake of sunflower**

Treatment	Medium P soil	High P soil	Mean
Drymatter (g/pot)			
100% RDP*	25.3	32.2	28.8
75% RDP	23.4	31.6	27.5
50% RDP	21.7	28.3	25.0
25% RDP	18.6	25.2	21.9
0% RDP	15.4	21.2	18.3
Mean	20.9	27.7	
CD (P=0.05)	Treatment : 2.1	Initial soil P : 1.5	Interaction : 3.0
P content (%)			
100% RDP*	0.274	0.349	0.312
75% RDP	0.260	0.301	0.281
50% RDP	0.234	0.286	0.260
25% RDP	0.213	0.230	0.222
0% RDP	0.209	0.224	0.217
Mean	0.238	0.278	
CD (P=0.05)	Treatment : 0.020	Initial soil P : 0.009	Interaction : 0.028
P uptake (mg/pot)			
100% RDP*	69.4	112.3	90.8
75% RDP	60.8	95.2	78.0
50% RDP	50.7	81.1	65.9
25% RDP	39.6	58.0	48.8
0% RDP	32.1	47.6	39.8
Mean	50.5	78.8	
CD (P=0.05)	Treatment : 5.2	Initial soil P : 2.4	Interaction : 7.3

*RDP = Recommended dose of phosphorus

Table 2 Effect of initial available soil P and fertilizer application on Pdff, fertilizer P uptake, per cent P utilization and soil P uptake of sunflower at flowering stage

Treatment	Medium P soil	High P soil	Mean
Pdff (%)			
100% RDP*	10.8	9.1	10.0
75% RDP	12.3	9.7	11.0
50% RDP	13.9	10.4	12.2
25% RDP	15.0	10.8	12.9
Mean	13.0	10.0	
CD (P=0.05)	Treatment : 0.8	Initial soil P : 0.5	Interaction : 1.1
Fertilizer P uptake (mg/pot)			
100% RDP*	7.48	10.23	8.86
75% RDP	7.49	9.26	8.38
50% RDP	7.06	8.43	7.75
25% RDP	5.95	6.24	6.10
Mean	7.00	8.54	
CD (P=0.05)	Treatment : 0.45	Initial soil P : 0.32	Interaction : 0.63
Per cent P uptake (mg/pot)			
100% RDP*	61.9	102.1	82.0
75% RDP	53.3	85.9	69.6
50% RDP	43.6	72.7	58.2
25% RDP	33.7	51.8	42.8
Mean	48.1	78.1	
CD (P=0.05)	Treatment : 4.7	Initial soil P : 3.3	Interaction : 6.7
Per cent P utilization			
100% RDP*	12.8	17.5	15.2
75% RDP	17.1	21.2	19.2
50% RDP	24.2	28.9	26.6
25% RDP	40.8	42.8	41.8
Mean	23.7	27.6	
CD (P=0.05)	Treatment : 1.9	Initial soil P : 1.3	Interaction : 2.7

*RDP = Recommended dose of phosphorus

The per cent P derived from the fertilizer in sunflower plants at flowering stage is significantly affected both by the level of P fertilizer application and initial soil P fertility status. The mean per cent Pdff tended to decrease significantly and sharply at the higher levels of P application when compared to that of lower levels of P application. In the past, when experiments were conducted on a nutrient deficient soil with different levels of that fertilizer nutrient, it was observed that the per cent nutrient derived from the fertilizer was higher with the increasing levels of fertilizer application due to its higher availability in soil (Subbaiah and Singh, 1970; *Khazanchilal and Dravid*, 1990; Sonali Mazumdar *et al.*, 2004). However, in the present study where in medium and high P soils were employed, the per cent Pdff in the plants tended to remain constant upto a certain level of P application i.e., up to 50% RDP and there after decreased sharply indicating that sufficient levels of available P is already existing in the soils as reflected by availability status. At the same time, it is also observed that with the increased P application to these soils, the contribution from the native soil P also became a major contributor in higher P fertile soil for crop requirement and the data on soil P uptake by plants presented in table 2 reflect the same. Consequently, the fertilizer P uptake by sunflower plants followed the trend *similar to per cent Pdff and the total P uptake (Table 1)* which was more influenced by the yield.

The applied P fertilizer use efficiency by sunflower plants was significantly affected by soil P fertility and P fertilizer application. The use efficiency of applied P was significantly higher in the plants raised on high P soil by about 16^ inspite the fact that the soil P uptake by the same plants was higher by about 83% when compared to that of plants raised on medium P soil. These observations point out that in a medium P soil with high P fixation capacity, the plants could use applied P to a certain level (23.7% in this case) after compensating for P fixation during the crop period. On the other hand, in a higher P fertile soil with almost similar soil characteristics, the use efficiency of applied P by this crop continues to be more indicating that the applied P remained in solution phase in larger quantities and probably for a longer duration due to lower P fixation capacity of the high P soil (42 when compared to 67% in medium P soil). Realisation of higher yields in high P soil was also one of the reasons for high use efficiency of applied P but, it was observed that the *application of higher levels of P fertilizer to this soil tended* to decrease the applied P use efficiency by the crop *significantly. The magnitude of decrease in applied P use* efficiency by the crops, once again, was more at high levels of P application within recommended dose.

The present study indicates that there is every possibility of reducing the P fertilizer input to sunflower crop when grown in P-accumulated vertisols without sacrificing the yield. It is also evident that the yield of the crop is higher in high P soil. But, these results need to be field verified for advocating P-fertilizer management strategies for crops in P-accumulated soils.

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Short communication

Bio-efficacy of some newer insecticides against *Spodoptera litura* (Fab.) infesting sunflower, *Helianthus annuus* L.[1]

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Sunflower (*Helianthus annuus* Linnaeus) is one of the most important oilseed crops in the world. In India, it occupies an area of 1.71 million ha with a production of 0.94 m.t. (Anonymous, 2001). In Andhra Pradesh, it is grown in 0.27 m.ha with a production of 0.16 m.t. (Anonymous, 2000).

Sunflower crop is often subjected to various lepidopteran pests among which, the important and most devastating pest is tobacco caterpillar *Spodoptera litura* (Fab.), which had developed resistance to many of the conventional insecticides like endosulfan, monocrotophos and carbaryl, etc. Hence, the present study was designed to evaluate the efficacy of certain newer and safer insecticides belonging to different groups, alone and in combination with *B.t.* at half of the normal concentrations against *S. litura* on sunflower.

The field study was carried out at Agricultural College Farm, Bapatla during *rabi*, 2001-02. The experiment was laid out in a Randomized Block Design with 12 treatments including untreated control replicated thrice. The size of each plot was 15 m^2 (5 m x 3 m). Recommended doses of NPK (80-60-40 kg/ha) were applied in the form of urea, single super phosphate and muriate of potash, respectively. The variety chosen for the experiment was APSH-11. During the crop period, the treatments were given as foliar sprays. The first spray was given at 50 days after sowing.

The data were collected on 10 randomly selected and tagged plants. The number of larvae on the tagged plants were counted a day prior to spray as pre-treatment count and post-treatment counts were taken at two, five, ten and fifteen days after treatment. The reduction of larval population over control was worked out by using the modified Abbott's formula (Flemming and Ratnakaran, 1985) and the data were subjected to statistical analysis. The percentage increase in yield over control in various treatments was also calculated.

Indoxacarb 0.145% was the most effective and significantly superior to all other treatments with 80.91% mean population reduction over untreated control after two days of first application (Table 1). However, treatments lufenuron 0.005% + *B.t.* 0.075% (21.23%) and neem 0.1% (16.04%) were less effective, while *B.t.* 0.15% (11.15%) and lufenuron 0.01% (12.34%) were on par and the least effective.

the observations recorded at five days after spraying revealed that the combination treatments and lufenuron, *B.t.* and neem alone showed significant increase in their efficacy while there was slight increase in the efficacy of indoxacarb and acephate alone. Ravi Kumar (1993) reported that acephate 0.1% effectively reduced the damage due to *S. litura* and *H. armigera* in groundnut.

Among the treatments, indoxacarb 0.00725% + lufenuron 0.005% was the most effective with 91.58% mean population reduction of *S. litura* over untreated control, but was on par with indoxacarb 0.00725% + *B.t.* 0.075% (89.74%). Among the treatments neem 0.1% (43.72%) was the least effective.

The data recorded at ten days after the treatment showed that the combination treatments were better than their corresponding individual treatments against the larval population of *S. litura*. The combination treatment, spinosad 0.01% + lufenuron 0.005% was the most effective among all the treatments with 72.69% reduction in larval population but it was on par with indoxacarb 0.00725% + lufenuron 0.005% (72.37%). Spinosad 48 SC (Spinosyn A+D) was reported to be highly effective against *S. lutura*. *Hellula undalis* (Fabricius) and *Plutella xylostella* of cabbage at a dosage level of 15-25 g a.i./ha (Dey and Somchaudhury, 2001).

Indoxacarb (0.024%) and spinosad (0.015%) showed 86.66% and 73.33 % ovicidal activity against *S. litura* (Ahmed *et al.*, 2001). Among the treatments neem oil 0.1% (25.63%) was found to be the least effective.

At fifteen days after treatment the combination treatments proved much better than their corresponding individual treatments, although there was slight build up of pest population in all the plots. Among the treatments, the

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combination treatment, indoxacarb 0.00725% + lufenuron 0.005% was the most effective with 50.03% reduction in *larval population* of *S. litura* and was on par with indoxacarb 0.00725% + *B.t.* 0.075%.

The overall mean efficacy showed that the combination treatments performed better over the corresponding individual treatments. The results showed that indoxacarb 0.00725% + lufenuron 0.005% (69.91%) and indoxacarb 0.00725% + *B.t.* 0.075% (68.05%) recorded the highest reduction of larval population and were on par with each other and significantly superior to all the other treatments.

The next best treatments spinosad 0.01% + lufenuron 0.008% (65.64), indoxacarb 0.0145% (65.55%) and spinosad 0.01% + *B.t.* 0.075% (63.54%) were on par with each other and recorded more than 63% reduction in larval population. Harikrishna (1996) indicated that lufenuron and profenofos were equally effective in reducing *S. litura* population on cabbage.

Table 1 Mean efficacy of the treatments after two sprayings against *S. litura* on sunflower during *rabi*, 2001-02

Treatment	Concentration (%)	Mean larval population/10 plants before spray	Reduction of larval population over control (%)				Overall mean efficacy	Mean yield (kg/ha)	% increase in yield over control
			2 DAT	5 DAS	10 DAT	15 DAT			
T_1 : Spinosad	0.0169	10.7	67.5 (55.3)	82.4 (65.3)	57.2 (49.1)	43.4 (41.2)	62.62 (52.3)	1377	49.4
T_2 : Indoxacarb	0.0145	9.5	80.9 (64.2)	75.7 (60.5)	60.0 (50.8)	45.7 (42.5)	65.6 (54.1)	1444	56.6
T_3 : Lufenuron	0.01	11.0	12.3 (20.4)	67.4 (55.2)	36.4 (37.1)	24.5 (29.6)	35.2 (36.3)	1155	25.3
T_4 : *Bcillus thuringiensis*	0.15	11.5	11.2 (19.2)	67.0 (55.0)	30.1. (33.2)	16.5 (23.8)	31.2 (33.9)	1089	18.1
T_5 : Neem	0.10	10.3	16.0 (23.5)	43.7 (41.4)	25.6 (30.4)	16.6 (23.9)	25.5 (30.3)	1056	14.5
T_6 : Acephate	0.075	10.5	62.6 (52.3)	59.1 (50.2)	31.1 (33.9)	25.4 (30.2)	44.6 (41.9)	1267	37.4
T_7 : Spinosad + Lufenuron	0.01+0.005	12.5	55.2 (49.0)	87.3 (69.3)	72.7 (58.6)	47.7 (43.5)	65.6 (54.1)	1444	56.6
T_8 : Spanosad + *B.t.*	0.01+0.075	11.0	54.6 (47.6)	85.1 (67.5)	69.1 (56.4)	45.5 (42.4)	63.5 (52.9)	1422	54.2
T_9 : Endoxacarb + lufenuron	0.00725+0.005	11.5	65.7 (55.2)	91.6 (73.5)	72.4 (58.3)	50.0 (45.0)	69.9 (56.8)	1656	79.5
T_{10} : Indoxacarb + *B.t.*	0.00725+0.075	11.0	64.0 (53.1)	89.7 (71.7)	70.3 (57.0)	48.3 (44.0)	68.1 (55.6)	1600	73.5
T_{11} : Lufeuron + *B.t.*	0.005+0.075	10.5	21.2 (27.3)	59.5 (50.7)	44.4 (41.8)	32.9 (34.4)	39.5 (38.9)	1244	34.4
T_{12} : Untreated control		12.0	0.0 (4.1)	0.0 (4.1)	0.0 (4.1)	0.0 (4.1)	0.0 (4.1)	922	-
F-Test			Sig.	Sig.	Sig.	Sig.	Sig.		
SEm±			0.6	0.7	0.5	0.6	0.5	0.04	-
CD (P=0.05)			1.4	1.8	1.5	1.8	1.5	0.10	-

DAT = Days after treatment
Figures in parenthesis are angular transformed values
(figures followed by same letters in each column are not significantly different)

Among the treatments neem 0.1% (25.49%) was found to be the least effective. This is in accordance with Bhanukiran *et al. (1997) who reported that neem oil 0.5%* was relatively less effective compared to other insecticides against *S. lutura* on groundnut. However, all the treatments were significantly superior over untreated control in bringing down the larval population of *S. litura*.

Based on the results obtained in the study, it is concluded that the use of toxic insecticides at lower doses in combination with *B.t.* is more promising in controlling the pests when compared to the individual sprays at higher doses. It is also useful in reducing environmental pollution and other hazards to beneficial organisms and human beings caused by them. Hence, using insecticides in combinations with lufenuron and *B.t.* is advocated in present day IPM.

The data pertaining to the yield of sunflower revealed that indoxacarb 0.0075% + lufenuron 0.005% recorded the highest yield (1655 kg/ha), but, it was on par with indocarab 0.00725% + *B.t.* 0.075 % (1600 kg/ha). The other treatments indoxacarb 0.0145% (1444 kg/ha), spinosad 0.01% + lufenuron 0.005% (1444 kg/ha), spinosad 0.01% + *B.t.* 0.075% (1422 kg/ha) were on par with each other. Among the other treatments *B.t.* 0.15% (1088 kg/ha) and neem 0.1% (1055 kg/ha) were on par and recorded significantly the lowest yields. However, all the treatments recorded significantly higher yields than the untreated control (922 kg/ha).

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Short communication

Efficacy of plant extract on mycelial growth and spore germination of *Alternaria tenuis* of sunflower, *Helianthus annuus* L.

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Sunflower seed is a source of high quality edible oil (45-52%) having higher content of polyunsaturated fatty acid. It also contains good quality protein (19 to 25%) in seeds and 35 to 40% in sunflower seeds meal (Raheja *et al.*, 1989). Despite its several merits, the crops is still subjected to the uncertainties because of rainfall fluctuations and plant protection problems. Yield losses due to the diseases in India were 11.5 and 17.5 % during 1986-87 and 1991-92, respectively. In Madhya Pradesh it is assuming commercial status, the major areas being *Jabalpur (1664 ha), Indore (243 ha)* and *Ujjain (4590 ha)* division. Currently, sunflower covers the area of 30,000 ha with 1350 kg/ha productivity. *Alternaria* leaf spot/blight is considered as a major disease and constraint in the cultivation of sunflower. The total failure of this crop at several places was mainly due to the disease even in wild and related species of *Helianthus* (Morris *et al.*, 1983). The disease not only causes losses in yield but also reduces oil content by 17 to 30% and quality of oil (Kolte, 1985). Hence, the investigation was undertaken to test the efficacy of plant extracts *in vitro* against *A. tenuis*.

Efficacy of extracts of 12 different plants were tested against *A. tenuis* (Table 1). Parts of different plants, collected from the JNKVV campus, Jabalpur were thoroughly washed in tap water and were cut into small pieces. The required quantity (100 g) of leaves was boiled (60°C) in 200 ml of tap water for 10 min. The aqueous extracts were filtered through cheese cloth and bacterial filters and volume made upto 100 ml with distilled water. Such extract were treated as stock solution and kept at 4°C for further use.

Table 1 Plants used as extracts for the control of *Alternaria tenuis* of sunflower

Common name	Botanical name	Family
Akaoua	*Calatropis procera*, Br.	Cynancheae
Lantana	*Lantana camera* L.	Verbineae
Gazer ghas	*Parthenium hysterophorus* L.	Compositae
Ashok	*Polyalthia longifolia pandula* (Scuser) Thio.	Aunosiaceae
Karanj	*Pongamia pinnata* (L.) Pierrc.	Pipilionaceae
Beshram	*Ipomea fistulosa* Martexchoisy.	Convolvulaceae
Neelgiri	*Eucalyptus globulus* Labill.	Myrtaceae
Tulsi	*Ocimmum sanctum* L.	Labiateae
Garlic	*Allium sativum*	Liliaceae
Lemon grass	*Cymbopogon flexuosus* (Neesexsteud) **Wats.**	Poaceae
Sada suhaganm	*Vinca rosea* L.	Apocynaceae
Datura	*Datura sp.* L.	Solanaceae

Standard methods i.e., poisoned food and spore germination techniques were employed to test the efficacy of plant extracts against *A. tenuis* as per the method described by Carpenter (1942). The fungus was isolated from leaf of sunflower (cultivar IV-81) grown in a research plot at College of Agriculture, JNKVV, Jabalpur. It was cultured on PA medium at 25°C and culture discs of 10 days old were used for the poisoned food and spore germination techniques.

The extracts of plants except *Cymbopogon flexuosus* significantly decreased the mycelial growth of *A. tenuis*. Initially no significant difference was observed among *Cymbopogon flexuosuss*, *Ipomoea fistulosa*, *Lantana camara*, *Calotropis procera* and *Pongamia pinnata* as compared to growth in control at 20% concentration. At this concentration minimum growth of 31.08 mm and 32.66 mm was recorded in *Polyalthia longifolia* and *Allium sativum* extract which were at par followed by *Datura* sp.

(35.25 mm) and *Vinca rosea* (36.00 mm). Similar reports have been made by various workers, Mishra and Dixit (1976) for *Allium sativum*; Lunger *et al.* (1990) for *Datura* and Datar (1992) for *Polyalthia longifolia*. At 30 per cent concentration the mycelial growth in ascending order was as *Polyalthia longifolia* (7.75 mm) > *Vinca rosea* (12.58) > *Allium sativum* (19.41 mm) > *Ocimum sanctum* (25.00 mm) > *Datura* sp. (30.91 mm).

All the plant extracts significantly inhibited germination percentage which ranged from 22.92 to 84.25. Higher concentrations wee more inhibitory than lower concentrations. At 20% concentration out of 12 plant extracts only five *viz.*, *Parthenium hysterophorus, Ipomoea carnea, Eucalyptus globulus, Allium sativum* and *Datura* sp., had less than 50% germination, at 30% concentration only three plant extracts i.e., *Calotropis procera, Eucalyptus globulus* and *Cymbopogon* flexnsns had more than 50% germination at 40% only *Cymbopogon flexuosus* had more than 50% germination. Minimum germination of 3.75% was recorded in *Allium sativum* followed by 5.5 and 7% in *Parthenium hysterophorus* and *Ipomoea fistulosa*, respectively (Table 2). These findings were in accordance with Shekhawat and Prasad (1971), Datar (1992), Ganeshan and Jaychandran (1993) and Shivpuri *et al.* (1997).

Table 2 Effect of plant extract on mycelial growth and spore germination of *A. tenuis*

Plant extract	Mycelial growth (mm) at concentration				Spore germination at concentration			
	20 %	30 %	40 %	Average	20 %	30 %	40 %	Average
Caloatropis procera	51.83	47.91	45.66	48.47	76.25 (60.85)	57.50 (49.31)	36.25 (36.98)	56.66 49.(05)
Lantana camara	53.00	47.83	45.58	48.80	51.25 (45.71)	35.25 (36.40)	22.50 (28.28)	36.33 (36.80)
Parthenium hysterophorus	47.16	45.16	30.16	15.27	35.00 (36.24)	13.25 (21.64)	5.50 (11.70)	18.08 (23.19)
Polyalthia longifolia	31.08	7.75	7.00	48.55	55.00 (47.87)	31.25 (33.87)	11.75 (19.98)	32.66 (33.94)
Pongamia pinnata	51.75	47.41	46.50	49.61	62.50 (52.24)	35.75 (36.71)	20.00 (26.55)	39.41 (38.50)
Pomea fistulosa	54.58	48.66	45.58	40.75	38.75 (38.47)	19.50 (26.19)	7.00 (14.33)	21.75 (26.33)
Eucalyptus golobulus	46.16	46.00	30.08	27.36	75.00 (60.05)	55.00 (47.87)	33.75 (35.50)	54.58 (47.81)
Ocimum sanctum	42.50	25.00	14.48	19.69	73.75 (59.25)	48.75 (44.28)	22.50 (28.28)	48.33 (43.93)
Allium sativum	32.66	19.41	7.00	52.57	32.50 (34.74)	11.00 (19.35)	3.75 (9.86)	15.75 (21.31)
Cymbopogon flexuosus	56.58	50.75	50.08	18.52	93.75 (76.53)	77.50 (61.71)	60.00 (50.78)	77.08 (63.01)
Vinca rosea	36.00	12.58	7.00	24.52	56.25 (48.60)	32.00 (34.44)	16.25 (23.73)	34.83 (35.59)
Datura sp.	35.25	30.91	7.41	56.55	32.50 (34.74)	19.00 (25.83)	11.75 (19.98)	21.08 (26.85)
Control	56.75	55.91	57.00		100.00 (85.94)	100.00 (85.94)	100.00 (95.94)	100.00 (85.94)
Average	45.79	37.33	30.28		60.19 (52.40)	41.24 (40.28)	27.00 (30.14)	

	Mycelial growth (mm) at concentration		Spore germination at concentration	
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Plant extract	1.81	5.017	0.86	2.41
Concentration	0.87	2.410	0.41	1.160
Plant extract x concentration	3.14	8.70	1.49	4.18

Figures in parentheses are transformed values

Mean of three replications

In the disease management, fungicide is a major component but the regular use of fungicide is a limited due to the cost and adverse environmental hazardes, besides development of resistance in pathogens (Wellman, 1977) and of late use of botanicals for the control of fungi is gaining importance (Dixit *et al.*, 1983; Fowcett and Spencer, 1990; Bisht and Kamal, 1994). Several higher plant and their constituents proved to be harmless and non-phytotoxic unlike chemical fungicide and have shown success in plant disease control (Spencer *et al.*, 1957; Shekhawat and Prasad, 1971; Appleton and Tansey, 1975; Mishra and Dixit, 1976).

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Short communication

Fertilizer management in groundnut + castor intercropping system under rainfed conditions in Tamil Nadu

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Castor, *Ricinus communis* L. is an important oilseed crop which brings a considerable amount of foreign exchange to the country. In India, the area under castor is 1076.7 thousand ha with a production of 866.6 thousand tonnes, with a yield of 805 kg/ha. The castor scenario of Tamil Nadu is that the crop is grown over an area of 38.9 thousand ha with a production of 12.7 thousand tonnes and an yield of 326 kg/ha (Damodaram and Hegde, 2002). The area under castor is abysmally low when compared to other states like Gujarat, Andhra Pradesh and Karnataka. This necessitates increased productivity and production in Tamil Nadu to cope with the growing demands.

In drylands, the major resources are rainfall and soil. Due to vagaries of monsoon, the productivity levels of the dryland crops are very low and unstable. Under such circumstances, intercropping will give additional income when main crop fails. Intercropping is an age old practice being followed by subsistence farmers to meet their domestic needs. The main advantage of intercropping is that the component crops are able to use resources differently and make better overall use of resources than when grown separately. The success of any intercropping system depends mainly on selection of component crops. The component crop should invariably have different maturity periods, growth rhythms and rooting patterns. This approach will also optimize the yield recovery of such system. Hence, the present investigation was undertaken to study the effect of fertilizer management in groundnut+castor intercropping on yield attributes and yield under rainfed condition.

Field experiments were conducted during the *kharif* seasons of 2000 and 2001 at Tapioca and Castor Research Station, Yethapur to study the effect of fertilizer management in groundnut+castor intercropping system (4:1) on yield attributes and yield under rainfed condition. The soil of the experimental field was low in available N (218 kg/ha), low in available P (8 kg/ha) and high in available K (680 kg/ha). The experiment was conducted in Randomized Block Design with three replications with 7 treatments.

The groundnut and castor were raised in 4:1 ratio. The recommended dose of fertilizer for rainfed groundnut *viz.*, 10:10:45 kg NPK/ha and for castor 40:40:0 kg NPK/ha was applied. The amount of rainfall received during the cropping period (July to February) was 792.6 mm and 676.8 mm in 2000 and 2001, respectively. The yield attributes *viz.*, no. of spikes/plant and 100 grain weight and seed yield in castor and pod yield in groundnut were recorded.

Castor yield attributes: The results of 2000 revealed that application of recommended dose of 10:10:45 kg NPK/ha for groundnut as basal to the entire system besides application of recommended dose of 40 kg N/ha in three splits *viz.*, 30, 50 and 70 DAS to castor recorded more number of spikes/plant and 100 seed weight. The results of 2001 and pooled analysis confirmed the findings of the first year.

Castor yield: The data on castor seed yield indicated that 100% RDF of base crop (groundnut) and 100% N of intercrop (castor) as top dressing on 30, 50 and 70 DAS recorded higher seed yield of 1329 and 1252 kg/ha during 2000 and 2001, respectively and with a highest pooled yield of 1291 kg/ha (Table 1). The possible reason for higher yields of groundnut+castor intercropping might be due to the supplementation of nitrogen synthesized in the root nodules of groundnut by the process of N fixation. This has resulted in enrichment and enhanced soil fertility which increased the overall herbage yield. In addition, rational supply of nitrogen through inorganic N source enhanced the castor productivity. Further, the better utilization of solar radiation enhanced the photosynthetic activity resulting in the higher yield.

Table 1 **Effect of fertilizer management in groundnut+castor intercropping system on yield attributes and yield of rainfed castor and groundnut**

Treatment	Castor			Groundnut	B:C ratio (pooled)
	No. of spikes/plant (pooled)	100 grain weight (g)	Seed yield (kg/ha)	Pod yield (kg/ha) (pooled)	
T_1 - Control (No fertilizer)	7.5	9.0	554	324	1.5
T_2 - 100% RDF of main crop to the entire system	10.0	14.5	909	686	2.1
T_3 - T_2+50% N of castor for top dressing in 2 splits at 30 and 50 DAS	13.5	15.5	1029	695	2.3
T_4 - T_2+75% N of castor for top dressing in 2 splits at 30 and 50 DAS	15.5	17.5	1134	831	2.5
T_5 - T_2+100% N of castor for top dressing in 3 splits at 30, 50 and 70 DAS	18.5	18.8	1291	1028	2.9
T_6 - 100% RDF of main and intercrop (area basis) (N of intercrop to be top dressed)	16.5	18.9	1221	828	2.5
T_7 - 100% RDF of main and intercrop	14.0	18.6	1049	693	2.1
CD (P=0.05)	3.0	2.5	45	32	-

Groundnut pod yield: The data on the pod yield of groundnut showed that 100% recommended dose of fertilizer to groundnut and in addition 100% N to castor as top dressing on 30, 50 and 70 DAS recorded higher pod yield of 1290, 766 and 1028 kg/ha during 2000, 2001 and in pooled data, respectively when compared to control (Table 1). It was expected that when the nitrogen was applied in splits based on adequate soil moisture availability, the nutrient uptake would have increased, resulting in higher yield attributes and yield.

From this study, it is concluded that application of recommended dose of fertilizer of base crop (groundnut) to the entire system, and application of 100% N of castor as top dressing in three splits at 30, 50 and 70 DAS resulted in higher yields in groundnut+castor intercropping system under rainfed condition.

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Short communication

Reaction of newly developed pistillate and inbred lines and their hybrids of castor to *Fusarium oxysporum* f.sp. *ricini* Nanda and Prasad

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Castor bean, *Ricinus communis* L. is an important non-edible oilseed crop in India. The crop suffers due to the attack of many seed and soil borne diseases of which *Fusarium* wilt is the important one. This disease is now becoming a serious problem in the country, especially in Gujarat where growing of castor after castor is a common practices. The extent of yield loss depends on the stage at which the plants wilt, 77% at flowering stage, 63% at 90 days after sowing and 39% at later stages on secondary branches have been reported (Anonymous, 2003). Though, the plants are infected at early stages of the crop, the symptoms are observed mostly at flowering and spike formation stages. As it is primarily a soil borne disease, the management through chemical or physical means is very difficult. The best option for management of this disease is the breeding for wilt resistant varieties/hybrids.

A number of resistant inbreds/hybrids have been developed in Gujarat (Golakia *et al.*, 2003; Kavani *et al.*, 2003). Present investigation was carried out to assess the differential reaction of castor hybrids derived from crossing between pistillate and inbred lines having variable resistant reaction to wilt disease.

On the basis of their previous performance for pistillateness as well as reaction to wilt, four pistillate lines *viz.*, JP 82, JP 87, JP 90 and JP 91 and eight inbreds *viz.*, JI 244, JI 258, JI 292, JI 303, JI 321, 48-1, DCS 9 and PCS 124 were selected to develop high yielding wilt resistant hybrids. The parents grown in wilt free plot during *kharif*, 2003 were crossed in line-tester fashion by hand crossing. The resultant 32 hybrids and their parents were screened during *kharif* 2003-04 for reaction to *fusarium* wilt in wilt sick plot established at the Main Castor-Mustard Research Station, Sardarkrushinagar, Dantiwada Agricultural University, Sardarkrushinagar. The experiment was laid out in Randomized Block Design with two replications. Each genotype was relegated to single row plot of 4.5 m length. The inter and intra row spacing of 60 cm and 30 cm, respectively, was maintained. All cultural operations were carried out as per the recommendations. Observations on resistant/susceptible plants were recorded at an interval of 30 days right from first appearance of wilt up to the crop maturity (180 days).

A perusal of results indicated that among the four pistillate lines, JP 82 and JP 87 showed susceptible reaction to the extent of 100% and JP 90 exhibited highly resistant reaction (8.3% incidence), whereas JP 91 recorded 64% incidence under wilt sick plot (Table 1). Eight male parents of hybrids showed varying levels of wilt incidence. The reaction ranged from 0.0% (immune reaction in JI 244, JI 258, 48-1, DCS 9 and PCS 124) to 76.9% (complete susceptible reaction in JI 321). The male line JI-303 exhibited 14.3% wilt incidence in (resistance reaction) wilt sick plot. The results indicated that large differences for resistance and susceptibility were present among the parents studied.

Incidence of wilt among the hybrids developed the pistillate lines and inbreds varied from 0 to 100% (Table 1). Out of 32 hybrids studied, JP 90 x JI 244 showed a immune reaction (0% incidence), while JP 90 x JI 258 exhibited resistant reaction (9% incidence). Remaining hybrids were either moderately susceptible or completely susceptible to wilt (50 to 100% incidence).

It is interesting to note that parents involved in the cross JP 90 x JI 244 and JP 90 x JI 258 were resistant and their offspring (F_1 hybrids) also expressed resistance reaction under wilt sick plot. Desai *et al.* (2001) reported that both the parents should be resistant to wilt when our objective is to develop wilt resistant castor hybrid. In contrary, though the cross JP 90 x 48-1 and JP 90 x DCS 9 involved both the parents highly resistant to wilt, produced moderately susceptible hybrids. This indicated that resultant hybrids would always not show resistant reaction even if the parents involved in cross combinations are resistant. This may be possible if one can expect the existence of modifier genes, which might have modified the degree of expression of resistant genes in the genetic backgrounds in which they were incorporated.

Table 1 Incidence of fusarium wilt in pistillate and inbred lines and their hybrids of castor

Parent / Hybrid	Wilt incidence (%)
Parents	
Females (Pistillate lines)	
JP-82	100
JP-87	100
JP-90	8
JP-91	64
Males (inbred lines)	
JI-244	0
JI-258	0
JI-292	73
JI-303	14
JI-321	77
48-1	0
DCS-9	0
PCS-124	0
Hybrids	
JP-82 x JI-244	64
JP-82 x JI-258	77
JP-82 x JI-292	67
JP-82 x JI-303	73
JP-82 x JI-321	93
JP-82 x 48-1	100
JP-82 x DCS-9	73
JP-82 x PCS-124	60
JP-87 x JI-244	53
Hybrids (Contd...)	
JP-87 x JI-258	78
JP-87 x JI-292	64
JP-87 x JI-303	53
JP-87 x JI-321	85
JP-87 x 48-1	50
JP-87 x DCS-9	50
JP-87 x PCS-124	100
JP-90 x JI-244	0
JP-90 x JI-258	9
JP-90 x JI-292	71
JP-90 x JI-303	58
JP-90 x JI-321	89
JP-90 x 48-1	53
JP-90 x DCS-9	67
JP-90 x PCS-124	67
JP-91 x JI-244	93
JP-91 x JI-258	100
JP-91 x JI-292	78
JP-91 x JI-303	53
JP-91 x JI-321	64
JP-91 x 48-1	60
JP-91 x DCS-9	71
JP-91 x PCS-124	79

Hybrids of susceptible and resistant parents, in general, had a tendency to show the disease incidence in the direction towards susceptible parent, indicating that the susceptible parents seem to have greater influence on deciding the wilt reaction. However, the hybrids like JP 87 x JI 244 (53%), JP 87 x JI 303 (53%), JP 87 x 48-1 (50%) and JP 87 x DCS 9 (50%) which were the combinations of susceptible x resistant parents expressed wilt incidence almost equal to mid parental values. This indicates that genes controlling wilt resistance might have additive nature in these crosses. Desai *et al.* (2001) also have reported the involvement of additive gene action in some of the crosses studied and suggested that wilt resistance characters in castor should be governed by polygenes.

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Short communication

Effect of potassium levels and spike order on the fatty acid composition of castor, *Ricinus communis* L.

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Fatty acid composition determines the quality of any edible or non-edible oil. Castor (*Ricinus communis* L.) a non-edible oilseed crop, is mainly cultivated in soils with poor fertility both under rainfed and irrigated conditions. Castor seed yields, oil quality and content are likely to be greatly influenced by these varying conditions. Significant responses to application of macronutrients (nitrogen, phosphorus and potassium) in improving castor seed yields in these low fertility soils have already been documented (Hegde, 2003; Murthy and Alivelu, 2004). Based on the soil fertility status, application of major nutrients influences the oil content and its quality (Golakiya and Patel, 2001; Nagaraj 2005). Very few fatty acid analysis of oil obtained from fertilizer experiments have actually been reported (Tiwari *et al.*, 2003). In general, location, season and spike position appear to have important roles on the quality of oilseeds. However, the information on specific effect of K fertilization on fatty acid composition of oil in castor is scanty. Amongst the three major nutrients, potassium appears to have the pivotal role on oil biosynthesis (Weber, 1985; Tiwari *et al.*, 2003). Keeping this aspect in view, the influence of potassium fertilization on fatty acid profile of castor oil extracted from seeds of primary, secondary and tertiaries was examined.

Field experiments were conducted with castor variety DCS-9 and hybrid DCH-32 separately during *kharif*, 2004 in a red sandy loam soil (Alfisol) at the Directorate of Oilseeds Research, Rajendranagar Farm, Hyderabad. The physico-chemical properties of the experimental soil *viz.* pH E.C., organic carbon, available nitrogen, phosphorus (P) and potassium (K) were 6.8, 0.18 dS/m, 0.3%, 180, 9 and 204 kg/ha respectively. Both the castor cultivars sown on 13th July, 2004 have received the graded K (muriate of potash) doses @ 0, 20, 40, 60, 80, 100 and 120 kg K_2O/ha while nitrogen and phosphorus were applied @ 60 kg/ha and 40 kg P_2O_5/ha respectively. The treatments were replicated thrice and a Randomized Block Design was adopted. All other cultural practices in vogue at the experimental farm were followed. Castor seeds of DCS-9 and DCH-32 were picked at 90, 120 and 180 days after sowing and seed yields were recorded. The oil was extracted into methanol and it was intensified using sodium methoxide. Fatty acid profile of the oil was determined by gas chromatography (Paquot, 1979).

Potassium fertilization showed significant influence on the total seed yield upto 20 kg K_2O/ha in DCS-9 and 40 kg K_2O/ha in DCH-32 (senior author's unpublished data). Similar response was observed earlier with DCS-9 (Murthy and Muralidharudu, 2003). Hence, castor seeds picked at three different days from the plots received 0, 20 and 40 kg K_2O/ha only were tested for fatty acid composition are presented in Table 1. Statistical analysis for the seed yield data of all the K treatments was done however, data pertain to the above three K levels only was reported.

Ricinoleic acid content, the key constituent of castor was relatively higher in third pick in DCS-9. A general decline in ricinoleic acid content was observed with increase in the K doses over pickings. Increasing doses of K showed an increasing trend in hydroxy fatty acid content in all the three pickings of DCS-9. Similar trends with respect to ricinoleic acid (range 86.8 to 88.7 %) were observed in DCH-32, castor hybrid also. However, they were higher than in DCS-9, which might be due to the hybrid vigour and better utilization of applied K doses.

Fatty acid profile of castor oil, in general, follows the order ricinoleic > linoleic > oleic > stearic > palmitic. Component fatty acids of the profile were however found altered by K application, wherein palmitic, stearic, linoleic, ricinoleic acids increased while oleic acid decreased when K was applied to DCS-9. Except in case of stearic acid, similar trends were not observed with DCH-32. In the present study, the observed orders of fatty acid profiles of DCS-9 and DCH-32 were ricinoleic > oleic > linoleic > palmitic > stearic and ricinoleic > linoleic = oleic > palmitic > stearic acids respectively. Alterations due to K application in fatty acid profile of different oilseed crops, except in castor were reported by Tiwari *et al.* (2003). Some of the alterations observed in fatty acid composition of castor oil, corroborate this view.

Table 1 **Effect of potassium doses on fatty acid profile of castor oil**

Genotype	Picking	K_2O dose (kg/ha)	Total fatty acid composition (%)					Seed yield (g/plant)
			Palmitic	Stearic	Oleic	Linoleic	Ricinoleic	
DCS-9	First pick	0	1.5	1.2	6.6	5.8	84.9	59.0
		20	1.6	1.3	6.3	6.1	84.8	64.2
		40	1.4	1.3	6.2	5.9	85.2	65.2
		SEm±						1.6
		CD (P=0.05)						4.9
	Second pick	0	1.3	1.4	6.5	5.9	84.8	49.2
		20	1.4	1.5	6.4	5.8	84.9	50.8
		40	1.6	1.4	6.3	5.7	85.0	64.6
		SEm±						1.9
		CD (P=0.05)						6.1
	Third pick	0	1.4	1.2	5.8	5.2	86.4	45.2
		20	1.3	1.3	5.7	5.3	86.5	49.6
		40	1.4	1.3	5.4	5.2	86.7	55.6
		SEm±						3.8
		CD (P=0.05)						11.8
DCH-32	First pick	0	1.5	1.2	5.3	5.3	86.8	64.4
		20	1.4	1.3	5.2	5.1	86.9	70.6
		40	1.4	1.4	5.3	5.1	86.8	125.0
		SEm±						16.6
		CD (P=0.05)						51.3
	Second pick	0	1.2	1.1	4.9	4.8	88.0	45.0
		20	1.2	1.1	4.8	4.9	87.9	50.0
		40	1.1	1.2	4.7	4.9	88.0	53.0
		SEm±						8.8
		CD (P=0.05)						27.2
	Third pick	0	1.1	1.0	4.6	4.7	88.7	47.4
		20	1.2	1.1	4.7	4.8	88.2	48.6
		40	1.3	1.2	4.6	4.6	88.3	42
		SEm±						10.8
		CD (P=0.05)						NS

These preliminary investigations clearly indicated the influence of increasing doses of K_2O application upto 20 kg/ha and 40 kg/ha for a castor variety and hybrid, respectively in improving and/or altering the fatty acid profile of oil extracted from seeds at different picking intervals.

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Short communication

Studies on natural outcrossing in TMVCH 1 hybrid castor, *Ricinus communis* L. seed production

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Castor, *Ricinus communis* L. belongs to the family Euphorbiaceae is one of the most important non-edible oilseed crop gains momentum as an important cash crop of dry as well as irrigated lands too. Commercial exploitation of hybrid vigour was successful in many of the field crops like rice, cotton, bajra etc. Attempts were also made in castor after the development of stable pistillate lines and numbers of hybrids have been evolved in India. Hybrid seed production in castor demands high level of technical expertise, special skill and training because of its complex sex mechanism and characteristic breeding system (Muralidharan *et al.*, 2001). In pistillate mechanism, the pistillate lines were maintained by the interspersed male flowers, the expression of which is highly sensitive to environment (Ramachandran and Ranga Rao, 1988). Since there is a limited work on the natural out crossing in seed production plots of hybrid castor, the present experiment was attempted to ascertain the factors responsible for enhancement of seed setting in TMVCH 1 hybrid castor, the first castor hybrid of Tamil Nadu. It is a cross between LRES 17 (pistillate line) and TMV5, released from Oilseeds Research Station, Tamil Nadu Agricultural University, Tindivanam, during the year 1998.

An area of one acre was selected with the isolation distance of 300 metre from other castor varieties and sowing was done during September 2003 at Agricultural Research Station, Tamil Nadu Agricultural University, Bhavanisagar. The sowing was taken up with the row ratio of three females : one male. The spacing adopted was 90x45 cm. One seed was placed per hill. Staggering of male parent (TMV5) at five and ten days later to the sowing of female parent LRES 17 (as the duration of female was higher then male) was done for synchronized flowering as well as for supplying pollen to the latter formed spikes. In addition, about 4-5 rows of male parents were raised as a border rows along all the sides of the field in order to ensure sufficient pollen load in seed production plot.

Observations on height of the plant, length of primary; secondary and tertiary spikes, and number of female flowers produced in primary; secondary and tertiary spikes, number of capsules produced in primary; secondary and tertiary order spikes were recorded on 20 selected plants of female parent. While rouging, the traits *viz.*, plant height, growth habit, stem color, bloom, branching nodes to primary raceme, nature of inter node, leaf shape, nature of spike, capsule and duration of male and female parents of TMVCH 1 hybrid castor were considered and the deviants if any were removed. Natural out crossing was assessed by estimating the seed setting percentages in primary, secondary and tertiary spikes on 20 selected plants in female parent. Further, the temperature prevailed during the emergence of primary; secondary and tertiary spikes of female parent (LRES17) was recorded as it plays crucial role in sex expression particularly pistillateness in castor.

Results of the study revealed that there was a significant reduction in seed setting as the crop proceeding towards the first (79.27%), second order (69.71%) and tertiary order (61.14%) spike emergence. The mean height of LRES 17 was observed to be 122.8 cm whereas the mean lengths of primary; secondary and tertiary spikes were 55.1 cm, 37 cm and 33.1 cm respectively. Similarly, the mean number of primary spike was one per plant while mean number of secondary and tertiary spike produced in a plant was observed to be 3.5 and 3.7 respectively.

Complete pistillateness noticed in all the orders of spike in the present experiment may be attributed to the temperature prevailed (maximum 30.2°C and minimum 14.5°C) during the emergence of different orders of spike. Hence, sowing of parental lines during September was found to be suitable for the production of complete pistillate flowers throughout the spike of female parent as the temperature was observed to be 30° or even less during the emergence of primary, secondary and tertiary spikes of pistillate lines. Therefore, it confirms that the temperature plays a crucial role in sex expression of castor. Similar results at DOR, Hyderabad have also been reported for the same pistillate line LRES 17 (Gopala Krishna Murthy *et al.*, 2003). As a consequence of complete pistillateness, selfed seeds seldom occur in hybrid seeds as the production of interspersed staminate flowers in pistillate lines is absent. In addition, staggering of parental lines and border rows of male parent are the other important factors seem to contribute for the natural out crossing in castor.

Present study indicates that the seed setting percentage was observed to be the highest in primary spike (79.27%) than latter order spikes. Present study confirmed that the temperature prevailed during the period of emergence of primary; secondary and tertiary spikes activated the female parent LRES 17 to produce pistillate flowers throughout the length of the spike and there by the self pollination by Interspersed Staminate Flowers (ISF) were avoided. Apart from the temperature, staggering of parental lines as well as raising border rows of male parent were the other important factors observed to favour the increased seed set through natural outcrossing. From the results it is understood that the sowing of seed production plot during September-October will be much rewarding for realizing the increased and genetically pure F_1 seeds of TMVCH 1 hybrid castor.

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Short communication

Management of castor wilt, *Fusarium oxysporum* f.sp. *ricini* through crop rotation

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Castor wilt caused by *Fusarium oxysporum* f.sp. *ricini* is one of the principal yield-limiting factors in the production of Castor (*Ricinus communis*) in the major castor growing regions in India (Anon., 1998). The disease is widespread and yield losses caused can be severe (55%). The disease can be managed to a certain extent by fungicide seed treatment as well as with the use of biocontrol agents. The disease can also be suppressed by a more economical and eco-friendly approach through crop rotation. The role of mono culture in increasing the disease incidence after each subsequent crop with reduction in yield is well documented (Merwe,1979). Crop rotation has been recommended as an effective management practice for wilts in different crop systems (Francis *et al.*, 1976; Kisel' -ov and Dukhanina, 1977). Previously Finger millet was recommended as an effective crop for crop rotation against wilt pathogen in castor (Anon., 1986). Keeping in view the potential of crop rotation as an effective management practice for wilt the present study was undertaken to test the effect of four different crops in rotation with castor in reducing soil inoculum load and wilt incidence.

Field trials were conducted in wilt sick soils of Directorate of Oilseeds Research. Hyderabad farm, Rajendranagar for two successive years (1999-2001). Four crops *viz.*,*Sorghum vulgare* (Sorghum cv. SH-15), *Pennisetum typhoides* (Pearl millet cv. BK-560), *Eleusine coracana* (Finger millet cv. Godavari), *Cajanus cajan* (Pigeonpea cv. ICPL-87) along with *Ricinus communis* (Castor cv. Aruna) were tested in rotation with castor in a Randomized Block Design with four replications to find an effective crop for minimizing the wilt infection in castor in a single year rotation. Each crop constituted a treatment.

The Inoculum load of the wilt pathogen was estimated before sowing and after harvest of each crop as per Sharma and Singh (1973) and expressed as colony forming units per gram of soil (cfu/g). Wilt incidence was recorded periodically through out the crop growth period when castor was sown after crop rotation. Yield data was also recorded and presented. Wilt incidence was calculated using the following formula.

$$\text{Wilt incidence} = \frac{\text{No. of plants showing wilt incidence}}{\text{No. of plants germinated}} \times 100$$

Wilt infection of 59.6 % and yield 350 kg/ha was recorded in the experimental plots before taking up rotation. On perusal of results it can be inferred that wilt incidence is markedly reduced to 20 % when castor was rotated with pearl millet in comparison to 64. 8 % disease recorded in castor - castor crop rotation (Table 1). Increase in disease incidence compared to preceding crop season was recorded in the later treatment. While percent reduction in disease incidence after a single year rotation ranged from 20.1 to 69.6 % in sorghum and pearl millet rotations respectively. Castor-pigeonpea and castor finger millet cropping sequence were found to be the next best alternatives recording 40.3 and 35.7 % reduction in disease compared to control. However, sorghum was found to be the least suitable crop among the different crops tested for rotation recording 52 % disease in comparison to 59.6 % wilt in previous season, *kharif*, 1999. The differences recorded with respect to disease incidence when different crops were used for rotation are in accordance to Zarzycka (1977).

Initial inoculum load of wilt pathogen was found to be 3.15 x 10^3 cfu/g of soil before the start of the experiment. No significant difference in the colony count was recorded at different locations of the plot. Inoculum load of the wilt pathogen varied markedly (1.39 - 3.37 x 10^3 cfu/g of soil) in different treatments after the crop season.

Minimum inoculum load (1.39 x 10^3 cfu/g) was recorded after rotation with pearl millet and it was superior to pigeonpea, finger millet and sorghum. The mean inoculum load of the wilt pathogen decreased from 3.15 to 2.35 x 10^3 cfu/g when rotation with different crops was taken up. In general, all the crops used in crop rotation trials resulted in decreased inoculum load of the wilt pathogen. Although sorghum was found inferior to other crops but was preferable to mono cropping in terms of reducing the *Fusarium* population in the soil.

Table 1 Effect of cropping rotation on soil population of *Fusarium oxysporum* f.sp. *ricini* and wilt incidence in castor

Treatment	Inoculum load of the wilt pathogen (x 10^3 cfu/g)				Wilt incidence (%)		Yield (kg/ha)	
	Duration rotation (1999)		After rotation		Reduction over control (%)		Increase in over control (%)	
	Initial	Final	Initial	Final	2000		2000	46.7
Castor-Sorghum-Castor	0	2.5	2.3	2.9	52.0 (46.2)	20.1	422	135.9
Castor - Pearl millet - Castor	3.3	1.4	1.0	1.7	20.0 (26.5)	69.6	678	106.5
Castor - Finger millet - Castor	3.1	2.3	2.0	2.6	42.3 (39.3)	35.7	594	113.0
Castor - Pigeonpea - castor	3.1	2.2	2.1	3.0	39.3 (38.8)	40.3	613	
Castor - Castor - Castor	3.2	3.4	3.4	4.2	65.8 (54.2)		288	
Mean	3.2	2.4	2.2	2.9	43.9		579	
SEm±	0.13	0.21	0.06	0.11	1.1		11.8	
CD (P=0.05)	0.4	0.65	0.19	0.34	4.7		36.3	

* Mean of four replications
Figures in parentheses are arc sine transformed values

After one-year rotation the same castor variety (Aruna) was sown in the plots and the *Fusarium* population in the soil and wilt incidence was monitored. Initial inoculum load of the wilt pathogen varied in different plots. Slight reduction in the population of *Fusarium* was recorded in the plots compared to observations taken during previous *Kharif*, 1999. The reduction in *Fusarium* population may be attributed to the non-availability of specific food source during the off-season. Plot sown with pearl millet recorded a minimum of 1.0 x 10^3 cfu/g of the pathogen followed by 2.0,2.1,2.3 and 3.4 x 10^3 cfu/g in finger millet, pigeonpea, sorghum and castor rotations respectively. Rotation with pearl millet not only reduced the population of *Fusarium* in soil but also the wilt incidence. When population of *Fusarium* was estimated in the same plots after the castor crop, increased inoculum load of 1.7, 2.5, 2.8 and 3.0 x 10^3 cfu/g was recorded under rotation with pearl millet, finger millet, sorghum and pigeonpea respectively. When castor was sown after castor there was sharp increase in the inoculum load to 4.20 x 10^3 cfu/g resulting in high wilt incidence (65.8 %).

Crop rotation with pearl millet recorded highest yield (678 kg/ha) resulting in 135.9 % increase over monocropping with castor (288 kg/ha). Pigeon pea and finger millet rotations recorded 113 and 106.5 % increase in yield respectively. Sorghum crop although found less effective than other crop rotations also recorded a significant increase in yield (46.7 %) compared to castor mono ropping . Single year crop rotation with certain specific crops like pearl millet can be practiced for increasing the yield significantly in wilt sick plots.

From the above results it can be concluded that crop rotation with pearl millet can be effectively employed for minimizing the wilt disease in wilt sick fields. Although, finger millet and pigeon pea rotations also showed some promise in minimizing the disease in wilt sick fields they can be regarded only as the next best alternatives to pearl millet rotation. It was also found that continuous monocropping of castor consistently increased the inoculum load and disease incidence.

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Short communication

Effect of seed treatment with biocontrol agents on castor, *Ricinus communis* L. seed germination, seedling vigour and grey mold disease

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Castor (*Ricinus communis* L.) is mainly grown in *kharif* (monsoon) season as a rainfed crop. Grey mold caused by *Botrytis ricini* Godfrey has emerged as a serious disease of castor causing severe losses when there are heavy and continuous rains coupled with high relative humidity during capsule formation stage (Anon., 1986). The pathogen being air borne in nature is very difficult to control. Fungicides provide certain degree of control against air borne pathogens, but at the same time they pollute the environment affecting the beneficial microorganisms. *Botrytis* spp. has been reported to develop resistance towards the regularly used fungicides (Haware and Mcdonald, 1992). Biocontrol agents are a possible alternative to fungicides. *Trichoderma harzianum* was reported to suppress *Botrytis cinerea* in grapes (Dubos, 1984) and apple (Tronsmo, 1980) under field conditions. The use of *Trichoderma* (Xu *et al.*, 1993; Boer *et al.*, 1998) and *Pseudomonas fluorescens* on different crops (Beastly *et al.*, 2001) in plant disease management has been well documented. Therefore, an attempt was made to study the effect of seed treatment with *Trichoderma viride, Pseudomonas fluorescens* and carbendazim on germination, growth of castor seedlings under lab conditions and incidence of grey mold under pot culture conditions.

A laboratory experiment and a pot culture experiment were conducted to find out the effective biocontrol agent against grey mold disease and its effect on seed germination and vigour index. Talc based formulations of *Trichoderma viride* and *Pseudomonas fluorescens* were obtained from the Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore for this study. Castor seeds (TMVCH 1) were treated with *Trichoderma viride* @ 4g/kg and 10 g/kg of seeds and *P. fluorescens* @ 10g/kg of seeds. Cabendazim @ 2g/kg of seeds was used as standard check. A control treatment (no treatment) was also maintained. Each treatment was replicated five times. Treated seeds were sown in the tray containing sand and watering was done daily in the morning and evening. Ten days after sowing, germination count was taken. Shoot and root length were also recorded. These seedlings were dried in hot air oven for two successive days for observing dry matter production. Vigour index was calculated based on germination and total seedling length.

Same set of seeds was sown in pots to find out the effectiveness of the biocontrol agents against grey mold disease. During spike formation stage, the pathogen (multiplied in PDA medium), *Botrytis ricini* spore suspension (10^6 cfu) were sprayed on the plants to all the treatments. One week after the treatment, grey mold incidence was recorded. The data collected were statistically analyzed and presented

Seed germination was observed from the seeds treated with *P. fluorescens* @ 10g/kg of seeds (92.5 %) which was followed by the seed treatment with carberdazim and *T. viride* @ 10 g/kg of seeds which recorded the germination of 90.0 and 87.5%, respectively (Table 1).

The seedlings raised from the seeds treated with *P. fluorescens* (10 g/kg of seeds), carbendazim (2 g/kg of seeds) and *T. viride* (10 g/kg of seeds) produced longer shoots of 21.5, 20.7 and 19.7 cm, respectively whereas the control (no treatment) recorded shorter shoot length of 18.0 cm.

Seedlings raised from the seeds treated with *P. fluorescens* (10 g/kg of seeds) also produced longer root length (7.9 cm) which was at par with that of carbendazim @ 2g/kg of seeds (7.9 cm). This was followed by seed treatment with *T. viride* (10 g/kg of seeds). Control (no treatment) recorded the least root length of 6.2 cm.

The highest total seedling length of 29.3 and 28.5 cm was recorded by seed treatment with *P. fluorescens* (10 g/kg of seeds) and carbandazim (2 g/kg of seeds) respectively whereas control (no treatment) recorded the lowest total seedling length of 24.9 cm. Similarly drymatter production of 208.5 and 205.3 mg/ seedling were recorded from seed treatment with *P. fluorescens* (10 g/kg of seeds) and carbendazim (2 g/kg of seeds), respectively whereas the control recorded the lowest dry matter production of 168.5 mg/plant.

Table 1 Effect of seed treatment with biocontrol agents on seed germination, vigour index and grey mold of castor

Treatment	Germination (%)	Shoot length (cm)	Root length (cm)	Total seedling length (cm)	Drymatter production (g/pl)	Vigour index	Grey mold incidence (%)
T_1 : Seed treatment with *Pseudomonas fluorescens* (10 g/kg of seeds)	92.5	21.5	7.9	29.3	208.5	2718	39.3
T_2 : ST with *Trichoderma viride* (4 g/kg of seeds)	85.0	19.2	7.5	27.0	191.3	2300	55.3
T_3 : ST with *T. viride* (10 g/kg of seeds)	87.5	19.7	7.7	27.2	191.5	2379	50.0
T_4 : ST with Carbendazim (2 g/kg of seeds)	90.0	20.7	7.9	28.6	205.5	2571	36.3
T_5 : Control (No treatment)	80.0	18.0	6.2	24.9	168.5	2091	66.2
CD (P=0.05)	13.0	12.0	1.5	2.7	23.9	434.8	9.7

ST : Seed treatment

The highest vigor index of 2718 and 2571 recorded by the seed treatment with *P. fluorescens* (10 g/kg of seeds) and carbendazim (2 g/kg of seeds) was followed by *T. viride* (10 g/kg of seeds) and *T. viride* (4 g/kg of seeds) recording the vigor index of 2379 and 2300, respectively.

The results of pot culture experiment revealed that the lowest grey mold disease incidence of 39.3 and 36.3% were recorded by seed treatment with *P. fluorescens* (10 g/kg of seeds) and carbendazim (2 g/kg of seeds) respectively. The other treatments *viz.*, seed treatment with *T. viride* (10 g/kg of seeds) and *T. viride* (4 g/kg of seeds) recorded the grey mold incidence of 50.0 and 55.3%, respectively whereas control (no treatment) recorded the highest grey mold disease incidence of 66.2%.

Seed treatment with *T. viride* @ 10 g/kg of seeds recorded the highest castor seed germination (Rama Bhandra Raju and Raoof, 2003). *Pseudomonas fluorescens* treated spikes exhibited 62% reduction in the grey mold incidence in castor (Raoof *et al.*, 2003). *Pseudomonas fluorescens* suppressed *Botrytis* blight up to 87 % in petunia flowers (Gould *et al.*, 1996). It may be concluded from the present studies that seed treatment with *P. fluorescens* (10 g/kg of seeds) and *T. viride* (10 g/kg of seeds) are effective in increasing the seed germination, plant growth, vigor index and decreasing the grey mold disease in castor.

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Short communication

Toxicity of *Bacillus thuringiensis* var. *kurstaki* strains and purified crystal proteins against *Spodoptera litura* (Fabr.) on castor, *Ricinus communis* (L.)

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The tobacco caterpillar, *Spodoptera litura* (Fabr.) is an important defoliator on castor crop throughout India, which appears usually from August and often becomes serious in October and November. Besides causing severe defoliation, the pest is also known to attack capsules and bore into the stems thereby resulting in breaking and falling of castor plants during heavy infestation or epidemics (Lakshminarayana and Raoof, 2005). The pest in general and the grown up larvae in particular are resistant to the commonly recommended insecticides in castor. Therefore, alternative pest control strategies need to be developed. Development of transgenics is one of the options available for enhancing host plant resistance to this polyphagous pest. Before embarking on the programme of genetic engineering there is a need to identify suitable candidate genes, which could be deployed into castor against this pest. It is known that *Bacillus thuringiensis* (*Bt*) var. *kurstaki* strains produce several lepidopteran toxic proteins such as Cry 1A(a), cry 1A(b), Cry 1A(c), Cry IIA and Cry 1B. The present investigation has been undertaken to assess the efficacy of *Bt* serovar *kurstaki* strains and the purified crystal proteins against *S. litura*.

Efficacy of *Bt* strains: Twenty one strains of *Bt*. serovar *kurstaki* (4D1 to 4D22) were collected from Bacillus Genetic Stock Center, OSU, USA. Protein purification was done as per the standard procedures and protein content was estimated using Folin-ciocalteau reagent according to Sadasivam and Manickam (1996) at A_{600nm}. These proteins were tested at concentrations of 125, 250 and 500 ng/ml against one and five day old *S. litura* larvae using the leaf paint assay method. A control was maintained by coating sterile distilled water on the leaves. Assays were carried out at 28°C and each treatment had three replicates and 10 larvae were released on 8.0 cm diameter castor leaves/treatment. Each treatment was repeated twice. Observations on the number of dead larvae were recorded at 2 days interval till 6 days after treatment (DAT).

None of the strains were found effective against both the tested instars of the target pest at concentrations of 125 and 250 ng/ml. Mortality of one-day old larvae on these low concentrations of protein at 6 DAT was less than 3.3%, which probably could be due to handling damage during bioassays and hence, were not subjected to analysis. Larval mortality at 6 DAT on leaves treated with higher concentration of protein (500 ng/ml) ranged from 0 to 50% and the mean cumulative larval mortaltiy ranged from 0 to 30%. None of the tested strains resulted in 100% mortality at the highest concentration tested even upto 6 DAT. Larval mortality was maximum with 4D1 (HD1) followed by 4D4 (HD 73).

The present study revealed that *Bt* strains harbouring serotype *kurstaki* can not offer complete protection against *S. litura*. The toxin specificity database (http://www.glfc.forestry.ca/bacillus/web98.adb) indicates that *Bt* strains with serotypes *aizawai, thuringiensis, entomocidus, galleriae, dermstadiensis* and *tolworthi* are inhibitory to few species of *Spodoptera viz., S. exigua, S. frugiperda* and *S. littoralis*. Hence, there is a need to test the efficacy of *Bt* strains of different serotypes against this generalist pest.

Efficacy of insecticidal crystal proteins: Six *E. coli* clones overexpressing *Bt*. proteins (Cry IIA, IAb, IF, IAa, IAc and IB) were obtained from the Bacillus Genetic Stock Centre, OSU, USA. The insecticidal crystal proteins (ICPs were isolated and purified as per Lee *et al.* (1992). The purified protein was solubilized and the toxin was tested at concentrations of 125, 250 and 500 ng/ml. Laboratory bioassays were conducted as per the procedure described for testing the *Bt* strains with the exception that 20 larvae were released per treatment and replicated thrice.

The 5-day old larvae displayed considerable tolerance and there was no mortality on the proteins tested and the concentration ranged tried. However, significant differences in mortality of one-day old larvae were observed (Table 1). At 2 DAT, mortality ranged from 0 to 50% and mean mortality ranged from 0 to 39.5%. Maximum mortality (39.5%) was recorded on leaves treated with Cry 1Aa and averaged over protein concentrations mortality was maximum on Cry IAa treated leaves. At the highest concentration of 500 ng/ml larval mortality was recorded on all the treatments but on Cry 1Aa larval mortality was observed on all the three concentrations. Larval mortality 4 DAT ranged from 0 to 66.7% and the mean mortality varied between 0 and 61.1%. The treatment effects on larval mortality 4 DAT with regard to the proteins tested and the concentrations tried was similar to the observations made at 2 DAT. In water treated control larval mortality was not observed.

Table 1 Efficacy of purified proteins of *Bacillus thuringiensis* on larval mortality and larval weight gain of *Spodoptera litura*

Protein	Concentration (ng/ml)	Mortality (%) 2 DAT	Mortality (%) 4 DAT	Larval weight gain (g) 6 DAT	Mean larval weight gain (g)
Cry IIA	500	2.2^{cd}	16.7^{bc}	0.041^{g}	0.084^{d}
	250	0	0	0.067^{g}	
	125	0	0	0.145^{defg}	
Cry 1Ab	500	9.25^{c}	33.3^{ab}	0.007^{g}	0.052^{d}
	250	0	0	0.018^{g}	
	125	0	0	0.027^{g}	
Cry 1F	500	2.77^{cd}	11.1^{bc}	0.077^{gfg}	0.030^{d}
	250	0	11.1^{bc}	0.007^{g}	
	125	0	0	0.005^{g}	
Cry 1Aa	500	39.5^{a}	61.1^{a}	0.080^{efg}	0.205^{c}
	250	15.1^{b}	55.6^{a}	0.253^{cde}	
	125	1.7^{cd}	22.2^{abc}	0.282^{cd}	
Cry 1Ac	500	2.1^{cd}	16.7^{bc}	0.300^{cd}	0.193^{c}
	250	0	11.1^{bc}	0.146^{defg}	
	125	0	0	0.133^{defg}	
Cry 1B	500	1.9^{cd}	11.1^{bc}	0.592^{a}	0.335^{b}
	250	0	0	0.169^{defg}	
	125	0	0	0.243^{cdef}	
Control	-	0	0	0.479^{ab}	0.479^{a}

Means followed by same letters are not different according to DMRT at P = 0.05
Percentage values were angular transformed prior to analysis
Data presented is for one-day-old larva
Each treatment had 3 replications with 20 insects each

Although there was no mortality with some of the protein treatments feeding cessation in terms of stunted growth and low larval weight gain was noticed. Larval weights recorded at 6 DAT revealed significant differences due to treatment effects. The larval weights varied between 0.005 and 0.592 g and was maximum on leaves treated with 500 ng/ml of Cry 1B. Averaged over concentrations, larval weight was maximum in control followed by the weight gain on leaves treated with Cry 1B. In Cry 1Aa treatment where maximum mortality was recorded, the larval weight was more as compared to the treatments with IIA, IAb and IF

Insecticidal δ-endotoxins of *B. thuringiensis* have acquired great significance in recent years because of their specificity to target pests, non-toxicity to humans and beneficial insects, toxicity at low concentration and environmental friendly nature. None of the purified proteins conferred 100% mortality against *S. litura*. Hence, there is a need to check for hybrid or engineered proteins as reported for *S. exigua* (de Maagd *et al.*, 1996) and *S. litura* (Singh *et al.*, 2004) for control of this polyphagous pest on castor.

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Short communication

Productivity and economics of intercropping systems involving safflower, *Carthamus tinctorius* L. under rainfed conditions

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Safflower is one of the efficient crops under rainfed conditions. Traditionally safflower is cultivated mainly in the states of Maharashtra, Karnataka and to limited extent in Andhra Pradesh on Vertisols on receding soil moisture conditions during *rabi* season. It is raised as an intercrop or mixed crop with other traditional crops like sorghum, wheat, linseed, chickpea, and coriander to improve the profitability of system. Different intercropping systems involving safflower are recommended to different ecological regions of India. Among these, intercropping of safflower with wheat, chickpea, coriander, linseed and mustard are prominent systems. To understand competition between crops, productivity and profitability of these intercropping systems and sole crop systems, an experiment was conducted on Vertisol under receding soil moisture conditions with recommended row ratios of these intercropping systems and sole cropping systems.

A field experiment was conducted during *rabi* season of 2002-03 at ICRISAT - DOR farm, Directorate of Oilseeds Research, Hyderabad. The soil of the field is characterized as Vertisol. The treatments consisted of five intercrop associations of wheat, chickpea, coriander, linseed and mustard with safflower (cv. Annigeri 1) and sole crop of safflower. Base crops of intercropping systems were also grown as sole crops in separate strip in a single replication. One row of wheat, chickpea, coriander, linseed was replaced by safflower after every 3 rows of base crop. In mustard + safflower intercropping two rows of mustard was replaced by safflower after every six rows of mustard. The experiment was conducted in Randomized Block Design with four replications. Chickpea, coriander, linseed and mustard were sown 30 cm apart. Wheat was sown 22.5 cm apart. Under sole cropping, safflower was sown 45 cm apart, chickpea, coriander, linseed and mustard was sown 30 cm apart and wheat was sown 22.5 cm apart. All the crops grown in intercropping were fertilized at their recommended dose of base crops. The seed rates used were as per recommendation for sole crops and intercrops as per percentage composition. The crops were sown on 22 October 2002. Amount of rainfall received during the rainy season was 543 mm. No rain was received during the *rabi* cropping season period. Safflower equivalent yield was calculated by converting the grain yield of all the crops in safflower seed yield on the basis of existing market price of the crops. Gross returns and net returns were computed using prevailing rates of produce and inputs. The economic parameters monetary advantage based on land equivalent ratio (LER) was computed as described by Jain and Rao (1980). The yields were further evaluated for different indices of competition functions as suggested by Willey (1979).

Sole stands of base crops recorded higher yield than their intercropping with safflower due to absence of interspace competition by intercrop (Table 1). One more reason could be attributed for lesser seed yields by base crops under intercropping situations was lesser population (75%) under intercropping compared to sole cropping (100%). Sole safflower recorded 2 to 4 times greater yield than intercropped safflower. It could be due to lesser plant population of safflower under intercropping (25%) than under sole cropping (100%). Dry matter production and seed weight of sole crop of safflower was significantly greater than that of intercropped safflower. Minimum dry matter and seed weight of safflower was recorded when it was intercropped with mustard. Safflower showed maximum reduction in yield in intercropping situation with mustard and minimum reduction with coriander and chickpea indicating greater productivity and higher stability of these intercropping combinations under receding soil moisture conditions.

Among the intercropping systems the highest total productivity in terms of safflower equivalent yield, gross returns, net returns and monetary advantage were recorded with coriander + safflower and chickpea + safflower in 3:1 row ratio indicating the additional advantage due to safflower is greater by replacing one row of coriander or chickpea with safflower (Table 1). The higher productivity and monetary return from intercropping of chickpea + safflower over sole cropping of base crop under receding moisture condition was also reported by Singh and Yadav (1992); Sarkar *et al.* (2000); Thakur *et al.* (2000). The higher productivity and monetary return from intercropping of coriander + safflower over sole cropping of base crop under receding moisture condition was also reported by Nikam *et al.* (1988). The higher productivity was due to additional advantage of intercrop yield i.e., safflower and also higher economic value of intercrop all the intercropping combinations performed better than their respective sole crops of base crops. Sole crop of safflower recorded significantly greater gross returns, net returns and B:C ratio compared to all intercropping combinations and other sole crops. It means it is better substitute of other crops under rainfed conditions. Sole crop of safflower performed better than sole crops of gram (Thakur *et al.*, 2000) and coriander (Nikam *et al.*, 1988) under rainfed conditions.

Considering the lower values of LER in intercropping system it can be inferred that intercropping systems for dry season on residual moisture hardly increases land use efficiency (Kumar and Singh 1987). All the intercropping combinations except linseed + safflower and mustard + safflower had LER greater than 1.00 (Table 2). Intercropping of safflower with chickpea and coriander recorded greater LER compared with wheat. The LER more than 1.00 shows greater biological efficiency of intercropping system (Rafey and Prasad 1992). Thakur *et al.* (2000) also reported that chickpea + safflower intercropping showed higher LER. The values of competition ratio indicated that mustard + safflower system had greater competition for resources like light, water and nutrients. The relative crowding coefficient revealed less advantage in yield in all the associations except coriander intercropped with safflower. The relative crowding coefficient of safflower in association with coriander and chickpea indicated an advantage derived from safflower under these associations. Safflower proved the dominant companion to mustard, having higher values of crowding coefficient. The product of relative crowding coefficient showed definite yield advantage under all the situations except intercropping of safflower with linseed and mustard which showed yield disadvantage. Sarkar *et al.* (2000) also showed advantage of chickpea + safflower intercropping in terms of relative crowding coefficient, product of relative crowding coefficient and monetary advantage. These facts are further supported by the aggressivity factor, where the reduction in yield of safflower is maximum when it is intercropped with mustard. Lesser values of aggressivity were observed when safflower was intercropped with coriander and chickpea.

It was concluded that sole crop of safflower may be more advantageous than intercropping of safflower with other traditional *rabi* crops. Among the intercropping systems, association of safflower with coriander and chickpea was more productive and profitable than other systems of intercropping.

Table 1 Productivity and economics of intercropping systems involving safflower

Treatment	Weight of safflower at harvest (g/plant)		Seed yield (kg/ha)		Safflower equivalent yield (kg/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit cost ratio	Monetary advantage
	Total drymatter	Seed	Base crop	Intercrop						
Intercropping system										
Wheat + safflower (3:1)	114	26	495	939	1175	5400	15274	9874	1.83	587
Chickpea + Safflower (3:1)	76	24	531	1075	1573	5550	20450	14900	2.68	2667
Coriander + Safflower (3:1)	89	30	377	1109	1689	5500	21957	16457	2.99	3190
Linseed + Safflower (3:1)	82	32	215	862	1087	5300	13135	7835	1.48	-406
Mustard + Safflower (6:2)	49	17	388	475	870	5500	11307	5807	1.06	-595
Sole crops										
Safflower	139	35		2166	2166	5300	28158	22858	4.31	
Wheat			800		381	3700	4960	1260	1.80	
Chickpea			820		757	5400	9840	4440	0.82	
Coriander			570		369	4800	11400	6600	1.38	
Linseed			375		260	2500	3375	875	0.35	
Mustard			530		652	5000	8480	3480	0.70	
S Em±	5.9	2.9		117	60					
C D (0.05)	18.7	9.2		369	185					
C V (%)	11.2	18.7		11.2	9.5					

(Cost of produce Rs/kg - wheat – 6.20; chickpea - 12.00; Coriander - 20.00; Linseed - 9.00; Mustard - 16.00; safflower – 13.00)

Table 2 Competition functions in intercropping systems involving safflower

Treatment	LER	Competition ratio	Crowding coefficient		Product of coefficient	Aggressivity	
			Ka	Kb		A1	A2
Wheat + safflower (3:1)	1.04	1.42	0.76	1.62	1.23	0.18	-0.18
Chickpea + Safflower (3:1)	1.15	1.30	0.98	1.84	1.80	0.15	-0.15
Coriander + Safflower (3:1)	1.17	1.29	1.05	1.95	2.05	0.15	-0.15
Linseed + Safflower (3:1)	0.97	1.43	0.66	1.34	0.88	0.17	-0.17
Mustard + Safflower (6:2)	0.95	3.32	0.28	2.73	0.76	0.51	-0.51

Ka- Crowding coefficient of safflower on base crop; Kb- crowding coefficient of base crop on safflower
A1- Aggressivity of safflower on base crop; A2- Aggressivity of base crop on safflower

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Short communication

Nature of variability, association and path analysis in niger, *Guizotia abyssinica* (L.) Cass

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Niger, *Guizotia abyssinica* Cass is a major oilseed crop and its yield levels are very low. Inspite of its wide cultivation and adequate germplasm investigations on its genetics have been rather meager. Simmonds (1962) quoted that advanced agriculture reduces variability, as when pure lines replace the land-races, when hybrid replaces the open pollinated varieties, and when advanced propagating techniques permit clonal multiplication in place of seedlings. These changes have all been made in the interest of genotypic adaptation and the gains have indeed been tremendous. The loss of variability incurred in the process has not only eliminated population adaptation as a factor in productivity but, had a detrimental effects upon adaptability.

Therefore, with the view of above points, sincere and concrete efforts were made for germplasm collection and evaluation for variability parameters and association and its practical exploitation. The present investigation is a part of this process.

After an initial evaluation of local collections of niger, selected 150 genotypes along with three checks were planted at Zonal Agricultural Research Station, Igatpuri in a Randomized Block Design with three replications. Each genotypes had three rows of 5 m length. Row to row spacing was kept 30 cm and plants were spaced at 10 cm within row. Recommended cultural practices were followed to raise healthy crop stand. Observations were recorded on five randomly selected plants for seed yield/plant and other seven yield attributing traits. Heritability and other variability parameters were estimated following Burton and De Vane (1953). Correlations and path analysis were computed as per Robinson *et al.* (1951) and Dewey and Lu (1959), respectively.

Significant differences among the genotypes of niger, suggested the presence of substantial variability for all the characters studied. The variability parameters such as range, mean, genotypic variance (GV), phenotypic variance (PV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance as percentage of mean (GA) are presented in Table 1. A wide range of variability was observed for all the characters. GCV was more or less equal to PCV. High to moderate heritability estimates were observed for all characters except plant height. No linear relationship among GCV, heritability and genetic advance was noticed but seed yield/plant and capsules/plant were found to have a high GCV along with high GA, suggesting predominant role of additive gene action. High heritability coupled with low GA was observed for days to flower, days to maturity, seeds/capsule, indicating the role of non-additive gene action for these traits. A low or moderate heritability with low GA was observed for plant height, suggesting that environment had a major role in their expression.

Genotypic and phenotypic associations are presented in Table 2. It revealed that the genotypic associations were higher in magnitude than their respective phenotypic associations, indicating that selection for correlated characters could give a better response that would be expected on the basis of phenotypic correlations (Robinson *et al.*, 1951). Thus, the present results are in general agreement with those of Sahu and Patnaik (1981), Goyal and Kumar (1985), Chennarayappa (1987), Mathur and Gupta (1993), Borole and Patil (1997) and Patil (2003). Seed yield was found to be significantly and positively associated with seeds/capsule, 1000-seed weight, plant height and capsules/plant. It was negatively and significantly associated with days to flower and days to maturity. Fifteen of the 28 phenotypic associations among eight characters were significant, only one of which was in negative direction. The negative associations were of seed yield with days to flower and days to maturity. A phenotypic as well as genotypic association among branches/plant, capsules/plant, seeds/capsule and 1000-seed weight and their positive association with seed yield/plant was observed indicating that these are the major yield contributing characters in niger. A selection for these characters would possibly be helpful in getting a quantum jump in yield increase of this crop. Ultimately, the nigher crop even though a minor oilseed crop will definitely increase its significant share among all oilseed crops, in

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the development of oilseeds economy of the country.

The importance of these characters was further analyzed by computing their direct and indirect effects on seed yield (Table 3). The path coefficient analysis based on genotypic and phenotypic associations revealed almost same pattern of direct and indirect influence of different characters on seed yield/plant. Thus, the results based on genotypic associations only are presented and discussed. Seeds/capsule had large and positive direct effect on seed yield followed by branches/plant, capsules/plant, days to maturity and plant height. Whereas, 1000-seed weight and days to flower had moderate direct effect in negative direction. The large direct effect of days to maturity, which has no direct bearing on seed yield is very difficult to explain. However, it was also reported by Sahu and Patnaik (1981). The direct and indirect effect of days to flower on seed yield was negative. However, it has positive effect via plant height, days to maturity and seeds/capsule. Thus, days to flower appears to be the components of these traits and not of the same yield.

Table 1 Estimates of different variability parameters in niger

Character	Range	Mean	Variance		Coefficient of variance		Heritability (%)	Genetic advance % of mean
			Genotypic (GV)	Phenotypic (PV)	Genotypic (GV)	Phenotypic (PV)		
Plant height (cm)	60-119	89	150.40	137.10	15.20	19.23	20.20	32.70
Days to flower	47-68	59	112.78	112.64	16.85	16.99	94.20	21.20
Days to maturity	89-119	100	137.06	137.07	12.64	12.68	92.50	18.40
Branches/plant	5-10	8	15.13	13.60	20.24	27.88	56.80	27.40
Capsules/plant	29-49	30	169.68	255.76	52.00	52.29	82.20	56.20
Seeds/capsule	21-46	29	24.05	36.61	23.86	29.29	76.20	20.40
1000-seed weight (g)	5-6	5	630.72	819.41	24.39	27.76	72.90	45.90
Seed yield/plant (g)	2-5	3	0.58	0.79	42.83	48.77	75.90	77.40

Table 2 Estimates of genotypic (below diagonal) and phenotypic (above diagonal) associations in niger

Character	Plant height (cm)	Days to flower	Days to maturity	Branches/ plant	Capsules/ plant	Seeds/ capsule	1000-seed weight (g)	Seed yield/plant (g)
Plant height (cm)	**1.00**	0.350*	0.320*	-0.008	0.102	0.261*	0.169	0.283*
Days to flower	0.421*	**1.00**	0.807**	0.071	0.001	0.709**	0.501*	0.624*
Days to maturity	0.379*	0.850*	**1.00**	0.228*	0.028	0.604*	0.307*	-0.561*
Branches/plant	0.260*	0.129	0.459*	**1.00**	0.089	0.098	0.093	0.073
Capsules/plant	0.130	0.005	0.088	0.211	**1.00**	-0.106	-0.110	0.090
Seeds/capsule	0.290*	0.810**	0.845**	0.370*	-0.271*	**1.00**	0.315*	0.670*
1000-seed weight (g)	0.240*	0.599*	0.397*	0.339*	-0.130	0.470*	**1.00**	0.304*
Seed yield/plant (g)	0.350*	-0.752**	-0.750**	0.159	0.252*	0.920**	0.444*	**1.00**

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

Table 3 Estimates of direct (diagonal) and indirect effects of component traits in niger at genotypic level

Character	Indirect effects via							
	Plant height (cm)	Days to flower	Days to maturity	Branches/ plant	Capsules/ plant	Seeds/ capsule	1000-seed weight (g)	Seed yield/ plant (g)
Plant height (cm)	0.160	-0.020	0.170	-0.010	0.010	0.050	-0.010	0.350*
Days to flower	0.100	-0.380	0.200	-0.270	-0.260	0.050	-0.192	-0.752**
Days to maturity	0.150	-0.263	0.190	-0.290	-0.302	0.090	-0.325	-0.750**
Branches/plant	-0.210	-0.190	0.270	0.304	-0.170	-0.140	0.295	0.159
Capsules/plant	-0.230	-0.080	0.198	0.172	0.192	-0.190	0.190	0.252*
Seeds/capsule	0.121	-0.005	0.190	0.119	0.104	0.401	-0.010	0.920**
1000-seed weight (g)	0.170	-0.097	0.282	-0.152	0.179	0.249	-0.187	0.444*

Residual effect = 0.145; *, ** Significant at 5% and 1% level, respectively.

Thus, for improving the seed yield and developing the high yielding genotypes of niger due emphasis should be placed in the improvement on branches/plant, capsules/plant, seeds/capsule and 1000-seed weight. As all these traits had high heritability coupled with moderate genetic advance, it may be possible to have a rapid gain by mass selection. Since late flowering beyond certain limit is not desirable, greater emphasis should be laid on early flowering, as it has significant and negative correlation with seed yield.

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Short communication

Assessment of genetic variability and character association in niger, *Guizotia abyssinica* Cass.

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Niger, *Guizotia abyssinica* Cass is an important minor oilseed crop of Ethiopia and India. In India, it is grown over an area of 0.45 m ha with a production of 0.11 m tonnes and productivity of 257 kg/ha (Giriraj Kulkarni, 2003). Niger seeds contain 35 to 40 % of oil, which is of very high quality for human consumption, culinary purpose, manufacture of cosmetics and soaps. Poor yields of the crop are attributable to its cultivation in marginal lands with negligible inputs and non-availability of suitable cultivars for diverse agro-climatic conditions. At present local types are predominantly grown which have low productivity and are of longer duration. Niger being minor oilseed crop, very little attention has been paid with respect to its genetic enhancement. Knowing existing genetic variability in the germplasm, understanding the genetic architecture of the crop, recognizing the interdependence between the characters and determining the direct and indirect contributions of various traits to the seed yield are imperative for effective plant breeding programme. The present study was conducted to analyze the variability, correlations and path analysis in niger to identify the traits which are associated with seed yield and the possibility of using these as selection criteria to enhance the yield potentiality.

The material used for the present study comprised of 100 germplasm lines obtained from AICRP on Sesamum and Niger, Jabalpur. A field experiment to study genetic variability was laid out in 10 x 10 simple lattice design with two replications at Department of Genetics and Plant Breeding, College of Agriculture, Dharwad during *kharif*, 2002. Each replication consisted of ten sub blocks each having ten varieties of one line each. Varieties in each sub block were allotted randomly. Each treatment was grown in a single row of 3 meter length with a spacing of 30 x 10 cm. Recommended agronomic practices were followed during the crop growth period. Five plants were tagged at random in each replication to record the observations 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. Heritability was computed as suggested by Hanson *et al.* (1956) and genetic advance as given by Johnson *et al.* (1955). Genotypic and phenotypic correlation coefficients were worked as given by Al-Jibouri *et al.* (1958). Path analysis was done as per procedure suggested by Dewey and Lu (1959).

Genetic variability, heritability and genetic advance are presented in Table 1. In the present study, number of capitula per plant and plant height showed high phenotypic and genotypic variance while it was moderate for number of seeds/capitulum. Other traits showed low magnitude of phenotypic and genotypic variances. High values of both PCV and GCV were observed for seed yield/plant, number of capitula per plant and number of seeds/capitulum. They were moderate for harvest index, number of primary branches and capitulum diameter while low for others indicating low magnitude of variability in the germplasm for the characters showing low PCV and GCV estimates. Characters exhibiting high heritability estimates and high genetic advance in present study were seed yield/plant, number of capitula/plant and number of seeds/capitulum. Similar observations were made by Patil (2000). These traits appear to be predominantly controlled by additive gene action and are more amenable for selection. High heritability with low genetic advance recorded for test weight and days to maturity indicates that they are controlled to greater extent by non-additive gene actions. It could also be attributed to the low genetic variability recorded for these characters in material studied. Low genetic advance reflects increased effect of environment on these traits and thus selection procedures involving progeny testing may be followed to improve them. A gene pool comprising of best lines could be created to use as base population for breeding programmes to evolve superior lines, varieties and hybrids.

In general, genotypic correlation coefficient values were found to be higher than those of phenotypic values. A significant and positive association was noticed between seed yield/plant and the traits plant height, number of primary branches/plant, number of capitula/plant, capitulum diameter, number of seeds/capitulum, test weight and harvest index at both genotypic and phenotypic levels. There was no significant association of seed yield per plant with days to 50 per cent flowering and days to maturity (Table 2). The present results are in general agreement with the results of Patil (2000) and Veerakumar (2002). Hence, selection at phenotypic level can be made considering associated traits will help in improving the yield. Falconer (1964) and Ashri *et al.* (1974) have *concluded that the strength and direction of correlation in* different character combinations depend on the nature of experimental material and environmental conditions under which they have been studied. Hence, in such studies, general trend in association of characters are more important than the actual value itself.

In the present study, seven characters namely number of primary branches, plant height, number of capitula/plant, capitulum diameter, number of seeds/capitulum, test weight and harvest index were selected for path coefficient analysis at both genotypic and phenotypic levels as they had significant correlation with yield in the genotypes studied. Path coefficient analysis revealed that plant height, number of primary branches/plant, number of capitula/plant and test weight had high magnitude of direct positive effect on seed yield/plant at both phenotypic and genotypic levels. Similar trend was observed by Lakshmi (1999) in a study on niger. Maximum indirect positive *effect was shown by number of primary branches through* plant height to seed yield. Capitulum diameter had a small negative direct effect on yield at both genotypic and phenotypic levels (Table 3).

Table 1 Variability parameters, heritability and genetic advance in niger

Character	Range		Mean	Phenotypic variance	Genotypic variance	PCV	GCV	Heritability	Genetic advance (% of mean)
	Minimum	Maximum							
Plant height (cm)	109.5	183.5	149.11	317.50	311.16	11.95	11.83	98.0	24.12
Number of primary branches	9.0	21.5	14.19	8.121	7.28	20.09	19.02	89.7	37.07
Number of capitula per plant	16.5	118.5	55.42	436.22	424.27	37.69	37.17	97.3	75.51
Days to 50% flowering	55.5	68.5	62.50	0.018	0.0166	5.31	5.17	94.9	10.38
Days to maturity	83.5	89.5	86.44	2.56	2.341	1.85	1.77	90.7	3.46
Capitulum diameter (cm)	0.80	1.45	1.05	0.029	0.024	16.23	14.58	80.7	26.67
Number of seeds/capitulum	13.0	53.0	26.96	89.19	87.06	35.03	34.61	97.6	70.40
Test weight (g)	2.85	4.38	3.51	0.127	0.110	9.98	9.47	90.1	18.52
Seed yield/plant (g)	0.85	5.55	2.19	1.245	1.229	50.82	50.49	98.7	103.65
Harvest index (%)	4.75	14.4	8.36	3.44	3.27	22.16	21.63	85.4	38.98

Table 2 Genotypic (r_g) and phenotypic (r_p) correlation coefficients among different yield components in niger

Character		Plant height	No. of primary branches	No. of capitula/ plant	Days to 50% flowering	Days to maturity	Capitulum diameter	No. of seeds/ capitulum	Test weight	Seed yield/ plant	Harvest index
Plant height	r_g	1.000	0.806**	0.599**	0.008	-0.079	0.483**	0.758**	0.478**	0.772**	0.262**
	r_p	1.000	0.750**	0.587**	0.011	-0.071	0.435**	0.738**	0.446**	0.758**	0.237*
No of primary branches	r_g		1.000	0.628**	0.099	0.009	0.512**	0.741**	0.443**	0.743**	0.240*
	r_p		1.000	0.595**	0.079	0.008	0.422**	0.694**	0.393**	0.699**	0.205*
No. of capitula/plant	r_g			1.000	0.033	0.078	0.545**	0.622**	0.435**	0.645**	0.306**
	r_p			1.000	0.029	0.070	0.483**	0.601**	0.414**	0.632**	0.281**
Days to 50% flowering	r_g				1.000	0.602**	0.121	0.045	0.069	-0.043	-0.038
	r_p				1.000	0.559**	0.114	0.048	0.064	-0.040	-0.027
Days to maturity	r_g					1.000	0.046	-0.009	-0.062	0.011	0.130
	r_p					1.000	0.071	-0.006	-0.061	0.010	0.093
Capitulum diameter	r_g						1.000	0.424**	0.314**	0.424**	0.145
	r_p						1.000	0.376**	0.257**	0.376**	0.115
No. of seeds/capitulum	r_g							1.000	0.437**	0.661**	0.282**
	r_p							1.000	0.404**	0.646**	0.258**
Test weight	r_g								1.000	0.519**	0.244**
	r_p								1.000	0.495**	0.214*
Seed yield/plant	r_g									1.000	0.298**
	r_p									1.000	0.275**
Harvest index	r_g										1.000
	r_p										1.000

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

Table 3 Direct (diagonal) and indirect effects of 7 major yield components on seed yield at genotypic (G) and phenotypic (P) levels in niger

Character		Plant height	No. of primary branches	No. of capitula/plant	Capitulum diameter	No. of seeds/ capitulum	Test weight (g)	Harvest index
Plant height	G	**0.399**	0.204	0.130	-0.029	-0.003	0.065	0.012
	P	**0.412**	0.154	0.121	-0.017	0.019	0.061	0.011
No. of primary branches	G	0.321	**0.253**	0.136	-0.031	-0.003	0.060	0.011
	P	0.309	**0.205**	0.133	-0.016	0.018	0.054	0.010
No. of capitula/plant	G	0.239	0.159	**0.217**	-0.033	-0.003	0.059	0.014
	P	0.242	0.122	**0.207**	-0.018	0.016	0.057	0.013
Capitulum diameter	G	0.192	0.130	0.118	**-0.060**	-0.002	0.043	0.007
	P	0.179	0.086	0.100	**-0.038**	0.010	0.035	0.005
No. of seeds/capitulum	G	0.302	0.188	0.135	-0.026	**-0.004**	0.059	0.013
	P	0.304	0.142	0.124	-0.014	**0.026**	0.056	0.012
Test weight	G	0.191	0.112	0.094	-0.019	-0.002	**0.136**	0.011
	P	0.184	0.081	0.086	-0.010	0.011	**0.138**	0.010
Harvest index	G	0.104	0.061	0.064	-0.009	-0.002	0.033	**0.046**
	P	0.098	0.042	0.056	-0.004	0.006	0.029	**0.047**

Residual effect (genotypic) = 0.3138; Residual effect (phenotypic (= 0.3339

From the present study, it can be concluded that maximum emphasis in selection should be given to plant height, number of primary branches, number of capitula/plant, test weight and number of seeds/capitulum for achieving greater improvement in yield levels.

Germplasm lines of niger used in the present study revealed considerable amount of variability for all the characters studied. GCV and PCV values were found to be high for seed yield/plant, number of capitula/plant and number of seeds/capitulum while they were moderate to low for all other characters. Heritability in broad sense was higher for all the characters studied. Genetic advance was high for seed yield/plant, number of capitula/plant and number of seeds/capitulum. A significant and positive association was noticed between seed yield per plant and all other traits studied except days to 50% flowering and days to maturity at both genotypic and phenotypic levels. Path analysis revealed that plant height, number of primary branches/plant, number of capitula/plant and test weight had higher magnitude of direct effect on seed yield/plant at both genotypic and phenotypic levels.

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Short communication

Comparative performance of different linseed, *Linum usitatissimum* L. intercropping patterns

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Linseed (*Linum usitatissimum* L.) is being grown mostly under rainfed agro-eco-system and to avoid risk mixed cropping systems are preferred. This system of cultivation is inconvenient and less efficient as compared to intercropping system. The cultivation of crops under irrigated situations has more potential and deserves to be fully exploited for linseed cultivation by evolving suitable agronomic practices. As intercropping system can provide yield advantage over sole cropping (Billore *et al.*, 1992). The present experiment was laid out at the experimental fields of Project Coordinating Unit (Linseed), C.S. Azad University of Agriculture and Technology, Kanpur with an objective to find out economically viable intercropping system for linseed growers.

A field experiment was conducted during *rabi* for three consecutive years (1996-98) on well drained sandy loam soil having low organic carbon, medium available phosphorus and potassium with slightly alkaline in reaction. The experiment was laid out in Randomized Block Design with three replications. There were 10 treatments that consisted of four sole croppings viz., linseed (Garima), wheat (K 8027), lentil (K 75) and mustard (Vardan) and six intercropping patterns of linseed (main crop) with wheat, mustard and lentil (sub-crop) in 4:2 and 6:2 row ratios. The sole crop of linseed, wheat and lentil were sown 25 cm apart in lines while row to row distance for sole crop of mustard was 50 cm. The inter-crops were sown in replacement series. The experiment was irrigated as per need of the treatments. Besides yield and economics monetary advantage index (MAI) as well as different competition indices like land equivalent ratio (LER), competitive ratio (CR) and relative crowding coefficient (RCC) were also calculated (Willey, 1979) for conclusion.

Intercropping of wheat/mustard/lentil with linseed (main crop) has reduced the linseed yield significantly as compared to its sole cropping (Table 1) mainly because of reduction in area. Hiremath *et al.* (1991) also observed yield reduction in linseed yield due to intercropping. The reduction in linseed seed yield varied from 56.95% with linseed + mustard (4:2) to 16.04% with linseed + lentil (6:1) may be due to the fact that mustard crop has created more smothering effect as compared to wheat and lentil. However, the reduction in linseed seed yield was observed to be less than the area due to border effect side rows. The seed yield of sub crops was also less as compared to their sole crops. It was observed that reduction in seed yield of sub-crop was varied from 84.41% with linseed + lentil (6:1) to 40.59% with linseed + mustard (4:2). The intercropping patterns could not bring treatment effect on linseed equivalent yield (LEY) but it was supernumerary in sole linseed (2026 kg/ha) followed by linseed + wheat (4:2) i.e., 1937 kg/ha.

Monetary advantage index was positive only in the case of linseed + wheat (Rs. 3346) and linseed + mustard (Rs. 489) in (4:2) row ratio because land equivalent ratio were observed greater than unity only in these two associations.

Intercropping patterns of linseed + wheat (4:2) and linseed + mustard (4:2) only gave yield advantage over sole cropping. The yield advantage in linseed + wheat (4:2) was observed to be 12% but that was only 2% in the case of linseed + mustard (4:2). In the intercropping of linseed + wheat (4:2), linseed and wheat gained 9% and 3% yield advantage over its sole cropping, respectively. Whereas in linseed + mustard (4:2) intercropping pattern, linseed get reduced by 7% but mustard gained 9% over their sole cropping that ultimately resulted into 2% yield advantage. The yield advantage in these two associations may also be explained on the basis of K i.e., product value of relative crowding coefficient. It was also more than unity only in these two associations. Intercropping linseed + mustard in 5:1 row ratio registered LER more than one in the studies of Pali *et al.*(2000) too. The yield advantage in linseed + wheat (4:2) pattern may possibly be attributed to combined effect of better utilization of soil moisture, sun light and nutrients by component crops. Billore *et al.* (1992) also observed beneficial association between linseed and wheat. The yield advantage in the case of linseed + mustard (4:2) might be due to plasticity of mustard crop.

Table 1 Seed yield, MAI and competitive indices of linseed based intercropping systems

Treatment	Seed yield (kg/ha)			MAI	LER			Competitive ratio of intercrops	Relative crowding *coefficient*			Aggressivity	
	Linseed	LEY	Total		Linseed	Intercrop	Total		Linseed	Intercrop	K	Linseed	Intercrop
L+W (4:2)	1196	2081	1937	+3346	0.59	0.53	1.12	1.80	0.72	2.27	1.63	-0.70	+0.70
L + M (4:2)	872	890	1660	+489	0.43	0.59	1.02	1.60	0.65	1.71	1.11	-0.13	+0.13
L + Lt (4:2)	1348	325	1780	-2928	0.67	0.22	0.89	0.66	0.99	0.59	0.58	+0.34	-0.34
L + W (6:1)	1347	1194	1718	-840	0.66	0.33	0.97	2.82	0.34	2.64	0.90	-1.40	+0.14
L + M (6:1)	1165	567	1621	-990	0.58	0.38	0.96	1.97	0.45	1.83	0.82	-0.46	+0.46
L + Lt (6:1)	1701	221	1968	-290	0.84	0.15	0.99	1.07	0.89	1.11	0.99	-0.07	+0.07
Sole linseed	2026	-	2026	-	-	-	-	-	-	-	-	-	-
Sole wheat	-	3911	1374	-	-	-	-	-	-	-	-	-	-
Sole mustard	-	1498	1333	-	-	-	-	-	-	-	-	-	-
Sole lentil	-	1418	1546	-	-	-	-	-	-	-	-	-	-
CD (P=0.05)	532	-	NS	-	-	-	-	-	-	-	-	-	-

Linseed yield, linseed equivalent yield and NMR are depicted on pooled basis while others are 3 years average basis
L = Linseed; W = Wheat; M = Mustard, Lt = Lentil
LEY = Linseed equivalent yield; MAI = Monetary advantage index; LER = Land equivalent ratio

The linseed crop has dominated the sub-crop lentil only in 4:2 row ratio as competition ratio (1.52), relative crowding coefficient (0.99) and aggressivity (+0.34) were highest for linseed in this association only. Whereas, sub-crops have proved their dominance on linseed (main crop) in all the remaining associations. It is also clear from RCC values that wheat and mustard crops have yielded more than expected but 6:1 row ratio excelled 4:2 in this regards. It might be due to higher competitive ability of wheat and mustard as compared to other crops. The superiority in the competitive ability of cereals (Patra *et al.*, 1990) and Brassica (Rana *et al.*, 2001) were also recorded by earlier workers.

Thus, it can be concluded that intercropping of linseed + wheat/mustard (4:2) row ratio is advantageous under irrigated agro-eco-system.

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